Understanding Convergent Innovation in Healthcare Technologies: Relational Models for Nascent Ecosystems

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Preface

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text.

It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text.

This dissertation consists of 64827 words and 71 figures, excluding references.

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Abstract

New developments such as 'Precision Medicine' and 'Digital Health' are emerging areas in healthcare technology, underpinned by '*convergent technology*' or '*cross-industry'* innovation. However, convergence results in greater uncertainty and influence from new knowledge and actors, including previously disparate technologies and capabilities, bringing specific challenges in the development of innovations. Although the literature addresses the context of technology convergence, there has been limited research reported on the how such innovation is effected in nascent ecosystems.

This qualitative research addresses identified literature gaps, initially by using a combination of ecosystem actor interviews (n=39) to understand the context, followed by five longitudinal in-depth case studies at innovator organisations. Case evidence was obtained from a combination of interviews (n=62), supplemented by field observations, primary documents and evidence from publicly available sources. The data was subjected to multiple coding methods, with plausible causal mechanisms identified through case and cross-case analyses.

The research findings identify a set of five interconnected *micro-processes* (early organisational routines) which together form a *non-deterministic activity system* that enables an innovator to *navigate* (the ecosystem), *negotiate* (a position within it) and *nurture* (the innovation and ecosystem). The research further identifies the importance of careful balancing between relationally focussed *credibility-seeking* and *advantage-seeking* actions as the main driver 'guiding' managers when developing the innovation, the associated business model(s) and value network in the evolving ecosystem.

A conceptual model and framework are developed to show the interrelationships between organisational routines, the activity systems and the ecosystem. In developing organisational capabilities, it is argued that *convergent innovation requires mostly incremental changes* (low depth of change) *across many organisational routines* (high breadth of change), which reduce the uncertainty of organizational change and thus increase internal acceptance.

These findings support the argument that innovators require a more '*systemic*' view of innovation and governance approaches contributing to the innovation and capabilities literature. From a practice perspective, the research provides mechanisms for building relational capabilities critical to innovation delivery.

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Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Background

Healthcare systems around the world face major challenges to meet the ever-increasing demands on services and to control costs (Abbasi et al., 2013; Christensen, 2000; Herzlinger, 2000, 1978; Kim et al., 2013). Increasingly, health systems are looking beyond the traditional industry, technologies and suppliers for solutions. These new approaches have the potential to change health delivery, and to drive a greater 'convergence' of medical and other technologies (Burns, 2012; Fish and White, 2014; Sharp et al., 2011). These 'cross-industry' (Enkel and Gassmann, 2010) or 'convergent' (Stieglitz, 2003) technologies, including nanotechnology, biotechnology, information technology, electronics and cognitive science (Venkatesan, 2010), will require diverse organisations to work more closely together to deliver solutions, at every stage in the value chain (Eselius et al., 2008).

Future healthcare technology value chains therefore face greater uncertainty and influence from organisations and institutions not traditionally part of the value network or industrial system (Rikkiev and Mäkinen, 2013). Understanding and addressing these challenges is potentially key to the success of enterprises designing, developing and supplying new healthcare systems and to delivering products and services that could transform patient outcomes and public health. The importance of convergent innovation in healthcare has been identified (Dube et al., 2014), but there is limited research on how this innovation is enacted.

1.2 How might convergence impact healthcare technologies?

The challenges in delivering quality, affordable healthcare have been long debated (Herzlinger, 1978). Healthcare represents a significant part of the economy for many countries, typically between 6 and 17% of GDP (OECD, 2013, p. 157). Health systems around the globe face major challenges to meet the ever-increasing care demands and to control costs (Abbasi et al., 2013; Christensen, 2000; Herzlinger, 2000, 1978; Kim et al., 2013). Consequently, most major economies are reviewing and transforming their healthcare systems (Abbasi et al., 2013).

Typically, healthcare systems currently operate using a 'fee for service' (FFS) model where payment is made for each visit or the duration of visit and services consumed (Thomson et al., 2013). Porter (2010a) and Christensen (2009) have both suggested that alternative models with FFS being replaced by a 'fee for outcome' (FFO) or a 'fee for membership' (FFM) depending on the treatment or care need. These types of solution have the potential to change healthcare delivery models, and one underlying feature is that they rely on innovation from outside the traditional healthcare sector (Thakur et al., 2012). This will drive a 'convergence' (Enkel and Gassmann, 2010; Hacklin and Wallin, 2013; Stieglitz, 2003) of medical and other technologies, from other industries, such as computing and digital, electronics and novel materials (Burns, 2012; Fish and White, 2014; Sharp et al., 2011). This may not just occur in the technology development but will likely happen at every stage in the value chain (Eselius et al., 2008). The magnitude of the potential changes is significant; McKinsey (Abbasi et al., 2013) have estimated the value of the 'shift in system' and potential savings, at $300-400 billion.

The changes identified have a consequential impact on the healthcare value chain actors:

- An increasing move towards payment for outcomes, as opposed payment for product or service (Christensen et al., 2009; Porter, 2010b)
- A move to more patient centric treatment and care delivery services requiring increased personalisation and precision (Herzlinger, 2001; Shaller, 2007)
- Convergence of medical technologies to create value adding new products, to simplify and reduce cost in the healthcare providers' delivery value chain (Burns, 2012; Downey, 2008; Eselius et al., 2008; Fish and White, 2014).

Sabatier *et al*. (2012) identified a number of '*new healthcare philosophies'* including personalized medicine, nanobiotechnology, and systems biology, all involving convergent technologies and '*incumbents from other sectors'*. Burns also identified that to deliver next generation of healthcare products, there is '*a need for technological convergence across sectors*' (Burns, 2012, p. 539). The technological changes have been described as the 'Third Revolution' (Sharp et al., 2011) and have the potential to produce highly disruptive innovations. Convergence in healthcare technologies will also impact healthcare provider businesses (e.g., hospitals) which are currently fragmented, and new initiatives like 'precision medicine' will change actors and business models (Bojovic et al., 2015; Fish and White, 2014; Mason et al., 2013).

The importance and relevance of 'convergence' or 'cross industry' (Enkel and Gassmann, 2010) innovation in healthcare is illustrated by the extent to which the major government health initiatives: for example, precision medicine, regenerative medicine, bioelectronics and digital health (Committee on a Framework for Development a New Taxonomy of Disease and National Research Council, 2011; Office for Life Sciences and Monitor Deloitte, 2015) are all underpinned by 'convergence'. This is depicted in Figure 1-1, which is derived from Shmulewitz et al (2006), Bernabo et al (2009a) and Kim et al (2012). This phenomenon has also been discussed recently by scholars (Dube et al., 2014), considering it as a 'meta-innovation' that also innovates the *way* innovation is conducted. This need, to consider different ways to innovate, is one driver for this research.

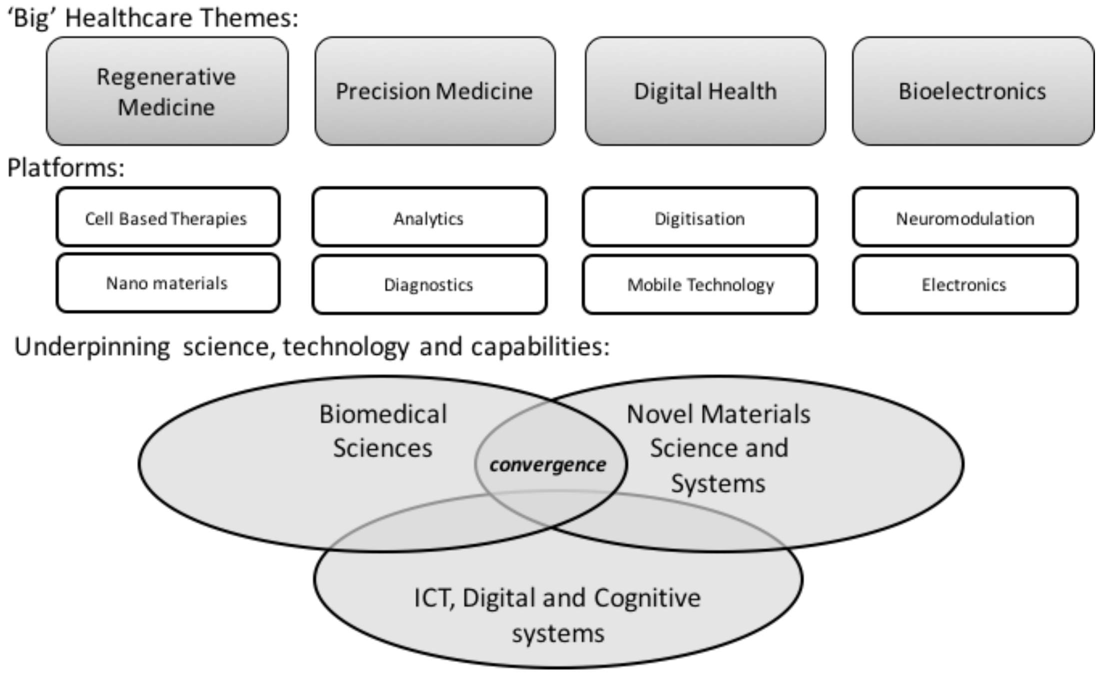

Figure 1-1 Importance of convergence in delivering new healthcare technologies (developed from Bernabo, Kim and Shmulewitz)

There is already evidence of cross sector engagement (Mack, 2017), which includes: alphabet (formerly Google) and Apple migrating towards healthcare. Recently, alphabet announced collaborations, via their Verily division, with Novartis on lens technology (Novartis, 2014) and with GlaxoSmithKline on bioelectronics (GlaxoSmithKline, 2016). Apple updated their iOS operating system to provide a personalized healthcare application (Apple, 2014), and their platform is now widely used by healthcare providers with over 75% of mobile digital health applications being on the iOS and Android platforms (Research2Guidance, 2016).

Healthcare technologies including pharmaceuticals, medical devices and diagnostics typically have long and complex supply chains that are typically not well managed, compared to other industries (Christensen et al., 2009). Like other industries, there is a trend towards fragmentation (disaggregation) of existing product value chains (Srai and Alinaghian, 2013), but at the customer-facing end of the value chain, there is a potential for integration or re-integration via new end-service provision and new business models (Kim et al., 2013; Porter, 2010a; Porter and Lee, 2013). However, healthcare technology companies have not historically been good collaborators and have limited expertise in customer facing ventures or in high value service provision (Burns, 2012, 2002), and so may find convergence and new ways to innovate a significant challenge.

The ecosystem is made more complex as new collaborators and alliance partners are likely to have divergent cultures, capabilities and perceptions, in terms of time, risk, investment, cost, and regulation (Mason et al., 2013; Rikkiev and Mäkinen, 2013). This presents challenges in developing not only the innovation, but also the required business model (Baden-Fuller and Mangematin, 2013; Zott et al., 2011) and value network (Srai et al., 2014; Sturgeon, 2001; Tsai and Ghoshal, 1998).

Given these multiple practice challenges and the limited previous research, the resulting challenge is in understanding how organisations innovate in this environment. Are existing innovation approaches using, for example, stage gates (Cooper, 1990) or open innovation (H. Chesbrough, 2006; Chesbrough, 2003) or disruptive innovation (Christensen et al., 2015; Danneels, 2004) practices satisfactory or do firms need to develop new capabilities? If so, how do they develop these capabilities? Do they employ dynamic capabilities (Teece et al., 1997) as has been widely accepted? Or, do they already need the required capability through organisational ambidexterity (Jansen et al., 2008; Raisch and Birkinshaw, 2008)?

Convergent innovation, with its potential to be disruptive, not only impacts existing innovation approaches, value chains and existing business models but also impacts the downstream healthcare pathways; it potentially changes the way healthcare is delivered. In this sense, it is 'systemic' (Midgley and Lindhult, 2017), suggesting that innovators and researchers need to take a wider 'systems' perspective to both the innovation and the innovation approach.

1.3 Motivation for this Research

The practice challenges stem from the rapidly changing environment with the formation of new 'ecosystems', and the ability of healthcare technology 'producers' to succeed by identifying, creating, delivering and capturing 'value' in the new and complex environment. Given the importance of healthcare systems and healthcare technologies to society, and the potential impact of 'convergence' and nascent innovation ecosystems, this research is of relevance, and importance, in helping identify approaches for future healthcare innovation.

1.4 Research Objectives and Contributions

The research aims to better understand how organisations innovate in healthcare technologies where the underpinning context is the convergence of technologies, across industries to create nascent ecosystems.

It is first proposed to develop an improved understanding of the ecosystem ‘, as a systems-based form of organising, providing a context for later research. This involves Identifying the system (and boundaries) from different perspectives, identifying key actors (or agents and stakeholders), their inter-relationships and their influence on activities, and identifying the dynamics and co-evolution through key trends, issues and opportunities

The main research objective is identifying how firms develop convergent innovations in these nascent ecosystems, with an emphasis on the value creation and capture activities, and capabilities required. This will involve exploring stakeholder requirements and analysing approaches to defining ‘value sources’, understanding how those ‘value’ requirements are translated via development of the innovation, business models and value networks into required capabilities and investment decisions. The aim is to develop frameworks that enable some linkage between the ecosystem, innovation processes, value network formation and organisation capabilities to be identified.

Finally, as well as contributing to the innovation and convergent innovation fields, the research will contribute towards the development of a more integrated or systemic approach and provide insights for practice. Given the importance of sustainable healthcare systems to us all, and the potential that new technologies may bring to achieving that; another aim is to contribute to healthcare ‘producers’ to improve their innovation approaches as a step to realising that potential.

1.5 Research Approach

The research predominantly focusses on ‘how’ organizations act, structure and organize for innovation, and secondly, to understand ‘why’ they adopted those approaches. Given the nature of the enquiry and the evolving nature of setting, a longitudinal qualitative approach was adopted (Anteby et al., 2014; Garud et al., 2013).

This research uses a longitudinal case study approach to explore these challenges by considering two aspects: an analysis of the **innovation ecosystem** (Adner and Kapoor, 2008; Autio and Thomas, 2014) itself: to assess the context, including the diversity of participants, the dynamics, and complexity of the emergent environment, by drawing on stakeholder theory and complex systems theory, and an **organisation and innovation capabilities** approach, to address value creation and capture in a nascent ecosystem via a **value network**.

As ‘systems’ are being investigated, a holistic multi-method approach is adopted (Midgley, 2011; Mingers, 2006), initially looking at system as whole, then focussing in on areas and activities that appear to have the greatest impact on overall behaviour and performance (see Figure 1-2). This approach provides context to enlighten the case observations (Garud et al., 2013; Pawson and Tilley, 1997).

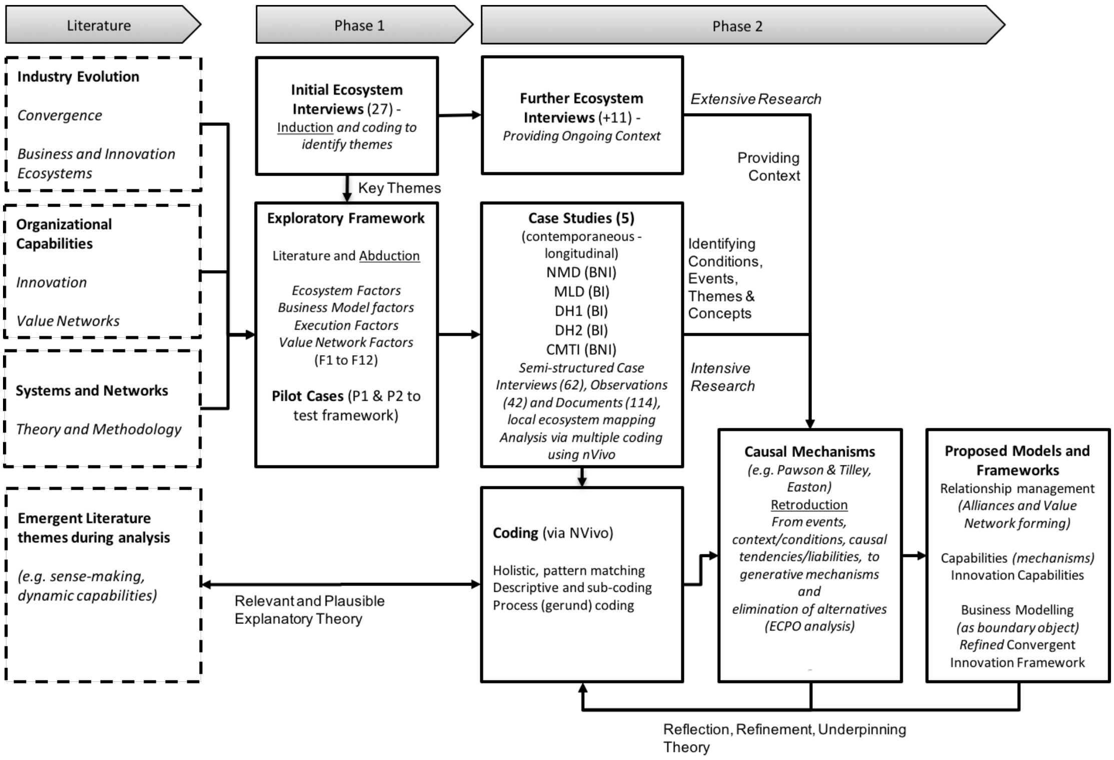

Figure 1-2 Overall research approach

1.6 Scope

This thesis will focus on the development of innovative technologies, products and services for healthcare (for example new diagnostic, treatment or patient management technologies), with a specific focus on 'convergent' medical products, which are defined here as those that bring two or more technologies from different industries (Enkel and Gassmann, 2010; Hacklin and Wallin, 2013; Stieglitz, 2003). Whilst it is intended that the frameworks and models developed will be relevant across healthcare, they will focus on using data and information from research primarily conducted in the UK.

1.7 Structure of this Thesis

Following this introductory chapter, Chapter 2 contains the main literature review covering the underpinning theory related to this research. Chapter 3 identifies the underpinning practice problems, the research challenges and gaps identified in the literature, to develop the emerging research questions. Chapter 4 describes the development of the research methodology and approach. Chapter 5 presents the preliminary research and the development of an exploratory framework, for use in the in-depth case studies. Chapter 6 presents the case studies and case findings. Chapter 7 provides cross-case analyses to identify patterns and differences. Chapter 8 discusses the proposed models in the context of existing literature. Chapter 9 summarises the key findings and the contributions of this research. Chapter 10 contains the References.

Appendices are included, containing supplementary information on the preliminary interview and case study protocols, the research sources and data, and key research analyses.

2 Literature Review

2.1 Introduction

The literature review starts by highlighting the practice challenges and then describes the underpinning theory relating to these challenges. The approach proposed provides a variety of perspectives, to enable a '*systemic view*' of innovation management, thereby building upon Malerba's (2002) multidimensional, integrated and dynamic view concept, and addressing the call for multi-level, longitudinal perspectives and context to be better recognized in innovation research (Garud et al., 2013).

The literature covers three main areas (see Figure 2-1). The first explores the context, the *underlying phenomena and dynamics of convergent innovation and innovation ecosystems*, a key focus being the implications, opportunities and challenges for innovators. The second takes an organizational perspective, to consider *innovation management* and *organizational capabilities* required and how these are developed**.** The third area considers the requirements for taking a 'systemic view', using *systems theory and thinking* and how this can be applied to the research methodology. This is separately covered in the Methodology (Chapter 4).

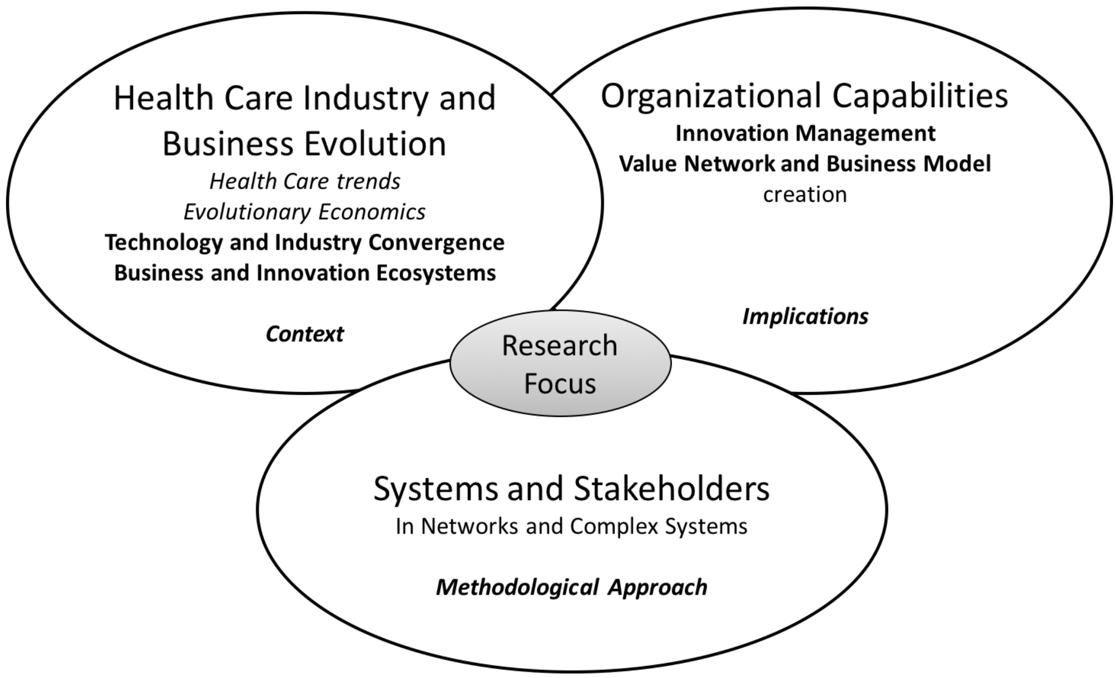

Figure 2-1 Scope of literature review

2.2 Industry Evolution and Convergence

2.2.1 Evolution and change

New industries are catalysed by technological change and characterised by high uncertainty (Benner and Tripsas, 2012). These changes are rooted in industrial evolution, a combination of incremental change (Marshall, 1921) punctuated with waves of 'creative destruction' (Schumpeter, 1947, 1939, 1928). Building on Alchian's (1950) initial concepts, Winter (1960) proposed and subsequently developed an evolutionary approach to economics (Nelson et al., 1976; Nelson and Winter, 2002, 1974, Winter, 1984, 1964), explaining evolution in terms of variation, selection, and retention. The concept of 'punctuated equilibrium' (Nelson, 1994; Romanelli and Tushman, 1994), also drawn from biology (Eldredge and Gould, 1972; Gould, 1980) describes an alternative approach to gradual change. Nelson (2002) extended the earlier evolutionary concept (Nelson and Winter, 1982) to address the co-evolution of technology, firms, institutions and industry. This concept of the co-evolution of technology, firms and institutions has more recently been developed by Geels (2014, 2005, 2002), considering these as *multi-level reconfigurations* using the concept of a 'triple-embeddedness framework', providing a perspective, addressing technological, economic and socio-political contexts, that is more 'systemic' (Senge et al., 2007). These evolutionary concepts are, however, rooted in an industry perspective.

A more recently studied phenomenon that impacts this evolution and firms' capabilities is 'convergence' (Hacklin, 2005; Stieglitz, 2003) or 'cross-industry' innovation (Enkel and Gassmann, 2010; Gassmann et al., 2010b), which may disrupt existing technologies, business models, industries and markets. The concept of disruptive innovations was re-popularised by Christensen (1997), exploring the impact of sustaining and disruptive change. Disruptive innovations tend to come from small entrepreneurial firms (Christensen, 1997) or involve new actors (Raynor and Christensen, 2002) and so to survive in the evolving environment larger incumbent firms need to adapt (Anderson and Tushman, 1990; Winter et al., 2000). However, the power of organizations to manage their routines may result in 'rigidities' (Leonard-Barton, 1992) and interfere with their ability to cope with the unexpected (Anderson and Tushman, 2001). Therefore survival is often linked to agility and the concepts such as "*dynamic capabilities*" (Easterby-Smith et al., 2009; Eisenhardt and Martin, 2000; Teece, 2007; Teece et al., 1997) that enable firms to create new capabilities. Rikkiev and Mäkinen (2013) identified convergence as a 'complex' phenomenon; they identified common themes in literature clustered around company strategy, management, process, people and offering; concluding that convergence reshapes existing industry value networks and, "*by using innovative business models and alliances, companies can find profitable positions or niche in new industry value chain*" (2013, p. 10). So, convergent innovation has the potential to be disruptive (Christensen, 2006), not only to change technology and products, but also create new industries (Stieglitz, 2003) or 'ecosystems' (Moore, 1993), new business models (Enkel and Gassmann, 2010) and markets, and thus requiring new capabilities (Barney, 1991; Leonard-Barton, 1992; Penrose, 1996). The following sections will explore each of these aspects.

2.2.2 Convergence as a phenomenon

As previously identified, there is evidence that healthcare products and systems will see a 'convergence' of technologies (Dube et al., 2014). In the literature the terms 'convergence' (Choi and Valikangas, 2001; Gauch and Blind, 2014; Hacklin, 2005; Hacklin and Wallin, 2013; Stieglitz, 2003), 'fusion' (Kodama, 1992; Rao et al., 2006) or 'cross-industry innovation' (Enkel and Heil, 2014a; Gassmann et al., 2010b; Heil and Enkel, 2015) are fields which exhibit similar phenomena. These phenomena include: working with knowledge and actors from different fields or industries (Enkel and Gassmann, 2010; Gassmann et al., 2011; Hacklin and Wallin, 2013), the need to search for more distant knowledge and partners to build new networks (Enkel and Heil, 2014a; Rikkiev and Mäkinen, 2013), the need to adapt innovation approaches (Enkel and Heil, 2014b; Heil and Enkel, 2015; Rikkiev and Mäkinen, 2013), and integration risks (Hacklin and Wallin, 2013; Rikkiev and Mäkinen, 2013).

'Convergence' in relation to industries and technologies has been used for four decades (Hacklin and Wallin, 2013; Stieglitz, 2003), but multiple definitions exist for it (Rikkiev and Mäkinen, 2013). For the purposes of this research, the following definition will be adopted: *using analogous knowledge with high cognitive distance or technologies of organisations outside their own value chain to develop innovative products and processes or business models* (Brunswicker and Hutschek, 2010; Enkel and Heil, 2014a; Gassmann et al., 2010a, 2010b).

Much prior research is in semiconductors, computing and communications technology, which saw waves of convergence in the 1990s and early 2000s (Bernabo et al., 2009b; Hacklin, 2005; Hacklin and Wallin, 2013; Stieglitz, 2003). There are limited studies in automotive (Bernabo et al., 2009a; Gassmann et al., 2010b) and biotechnology (Bernabo et al., 2009a; Eselius et al., 2008; Shmulewitz et al., 2006), which largely address the trends and industrial implications, and there are a small number of papers exploring early research challenges (Roco, 2003; Sharp et al., 2011; Venkatesan, 2010) in the field. But in healthcare technologies, despite several practitioner articles (Eselius et al., 2008; Gupta et al., 2013; Mason et al., 2013; Rajan and Frost & Sulivan, 2014), there is limited academic literature (Bernabo et al., 2009a; Dube et al., 2014; Ramachandran et al., 2011; Shmulewitz et al., 2006) and little evidence of empirical research. However, there are a few studies examining the implications for technological or business model discontinuities (Bojovic et al., 2015; Sabatier et al., 2012) and more broadly health systems convergence (for example Kim et al., 2013; Porter, 2010a; Porter and Lee, 2013), which is outside the scope of this research.

Convergence has been classified as either 'substitution' or 'complementarity' and to be either technology or product focused (Stieglitz, 2003), resulting in four convergence types (Table 2-1).

Table 2-1 Types of industry convergence (from Stieglitz, 2003)

	Substitution	**Complementarity**
Technology-based convergence	***Technology substitution***	***Technology integration***
Product-based convergence	Product substitution	Product complementarity

Following this reasoning, the convergent technologies in the healthcare ecosystem can be classified as largely *'technology-based convergence'* and therefore likely to lead to 'technology substitution' or 'technology integration' paradigms; "combining of new or existing technologies previously associated with different established industries into a new product, process or service" (Rikkiev and Mäkinen, 2013). Here, making correct choices amongst many technologies is considered important, together with a strong ability to integrate those technologies (Iansiti and West, 1997). The innovation does not need to be 'radical' (Partanen et al., 2014; Sainio et al., 2012; Slater et al., 2014) as incremental innovations in one industry, that cross industry boundaries, can create disruptive innovations in others (Hacklin, 2005) through four life-cycle stages: (1) 'knowledge convergence', (2) 'technological convergence', (3) 'applicational convergence', and (4) 'industrial convergence' (2010). Given the nascence of convergence in healthcare technologies (Dube et al., 2014), the expectation is that knowledge, technology and early application convergence will constitute much of the current field.

2.2.3 Technology evolution and the impact of convergence

The role of technological innovation has been the source of much research (Devezas, 2005; Dosi, 1997, 1982; Malerba et al., 1999; Nelson, 1994; Romer, 1990; Tushman and Anderson, 1986). Tushman and Anderson (1986), concluded that breakthroughs, or technological discontinuities, significantly increase environmental uncertainty. Dosi (1997, 1982), borrowing from Kuhn's earlier work on scientific advances, proposed '*technological paradigms*' or '*technological trajectories*', with relatively minor technological developments along a pattern, set by a paradigm. This concept results in path dependence, with new designs building upon the previous (Page, 2006; Vergne and Durand, 2011). A related concept, the '*dominant design*', further argues the importance of the technological evolution on an industry (Abernathy and Utterback, 1978; Murmann and Frenken, 2006; Suarez and Utterback, 1995; Utterback and

Suarez, 1993; Utterback and Abernathy, 1975). There is an expectation of a high degree of path dependence: "*As a first approximation, ... , firms may be expected to behave in the future according to the routines they have employed in the past*" (Nelson and Winter, 1982, p. 134); routines form the basis of organizational learning and capabilities. However as the technology matures, firms may also look downstream to diversify, but alternatively, it may result in a re-direction of effort (Fai and von Tunzelmann, 2001).

But with convergence, firms look outside their industry, thus breaking the path dependent trajectory (Dosi, 1982; Karim and Mitchell, 2000), and this results in emergence (Adner and Levinthal, 2002; Probert et al., 2013). Consequently, new learning must be acquired. Technology convergence is only part of the challenge, intercompany collaboration is one of the primary strategies in convergence (Bores et al., 2003; Lee et al., 2012) with most innovation happening at the boundaries between disciplines (Hacklin and Wallin, 2013). Rim et al (2009) explored convergence between media and telecommunications, which resulted in '*rebundling*' of value chains to create a '*composite business model'*. As Choi (2001) suggests, convergence results in "*blurred boundaries between industries by converging value propositions, technologies and markets*". The phenomena are complex, potentially requiring a multi-faceted approach to explore them (Anteby et al., 2014). So, as a conclusion, an industry perspective is considered inappropriate as convergence invariably involves multiple industries, and the creation of new ecosystems. This suggests an ecosystem perspective as potentially more fruitful to study convergent technology innovation.

2.3 Business and Innovation Ecosystems

Following its initial appearance in practitioner outlets (e.g. Moore, 1993; Iansiti & Levien, 2004), the ecosystem concept has featured increasingly in leading management and organization studies journals, including the *Academy of Management Review* (e.g. Alexy et al., 2013; Priem et al., 2013); *Organization Science* (e.g. Jacobides & Tae, 2015; Wareham et al., 2014) and *Strategic Management Journal* (e.g. Ansari et al., 2016; Kapoor & Furr, 2015; Pierce, 2009). Ecosystem research has highlighted the managerial relevance of viewing organizations and their environments as systems, characterised by interdependence, co-evolution, non-linear behaviour and scalable, system-level opportunities and challenges (e.g. Adner, 2012; Moore, 1993; Priem et al., 2013). In contrast to the classical 'market focus', ecosystem studies have explored users, complementors and producers in network markets (Frels et al., 2003), identifying the role of 'platforms' in creating connectivity between actors (Gawer and Cusumano, 2013; Wareham et al., 2014) and examining their emergence and evolution (Ansari et al., 2016). The concept of an 'innovation ecosystem' (Adner and Kapoor, 2010; Autio and Thomas, 2014) , would appear to provide a relevant context for this research. A review of recent ecosystem literature (for exmaple, Adner and Kapoor, 2016; Kapoor and Lee, 2013; Rong et al., 2015; Rong and Shi, 2015; Shang et al., 2014) identify that it focuses largely on *what* an ecosystem is, and *what it is for*, with *limited focus on how* they are designed or created, and the processes operating within them.

Importantly, ecosystem research expands the boundaries of organizational research to achieve a more holistic view (Autio and Thomas, 2014), but the field arguably lacks a more coherent methodology to support its further development. To illustrate this deficit, the seminal papers (top 20 cited *business or innovation ecosystem* in the ISI Web of Science), including for example Moore (1993) and Iansiti and Levien (2004), rarely elaborate explicit systems thinking or systems approaches. Recent reflective critiques and reviews (Badinelli et al., 2012; Oh et al., 2016) have noted the same issues. Badinelli et al. noted that "*much of the use of the word 'system' in literature merely describe interconnectedness of entities, but do not adhere to systems thinking principles, which often disrupt the traditional thinking*" (2012, p. 499). In their recent overview, Autio and Thomas (2014) found that while many systems-related concepts were used in ecosystem research, there was no explicit reference to systems thinking or methods.

Although a number of approaches have been proposed to the study of ecosystems, including prior research on networks (Lin et al., 2009; Rong et al., 2015) or on institutionalization (Vargo et al., 2015), there is no strong or prevailing theoretical and methodological approach. Where systems-like approaches are used, they have tended to focus on structure and specific phenomena (Anggraeni et al., 2007). This may in part be due to early research that focused predominantly on the structure of ecosystems and identification of key actors and their roles. Some notable exceptions who take a systems perspective include those approaching them as technical systems (Adner & Kapoor, 2010; Baldwin & Clark, 2000; Gawer & Cusumano, 2013; Kapoor & Furr, 2015) or as economic systems (Jacobides and Tae, 2015). Some studies, including Peltoniemi (2006) and Váncza et al. (2011), have adopted a broader, complex systems approach, but these remain a minority within the larger body of ecosystem studies.

Among the multiple ways of exploring such phenomena as business or innovation ecosystems, a narrow approach may be more appropriate in addressing theoretical and empirical questions such as how ecosystem actors and their linkages are structured (Basole et al., 2016; Still et al., 2014), or how a hub firm manages governance tensions inherent in the system (Wareham et al., 2014). However, "*the smaller the unit of analysis, the more one loses of the connectedness that is the very essence of the network*" (Easton, 1995, p. 417). There is currently no 'meta-level' methodological approach to systems-based forms of organizing to match the theoretically ambitions of ecosystem scholars, such as co-evolution (Adner and Kapoor, 2010) or collective institutional logic formation (Vargo et al., 2015). Among the perceived shortcomings of narrower approaches, the multitude of different studies in the current literature differ in their focus and level of analysis—an effect that is especially visible in the recent ecosystems literature (e.g. Oh et al., 2016). This diversity makes synthesis and cross-study inferences more problematic (Ritala and Almpanopoulou, 2017), inhibiting the development of a solid theoretical and methodological base and potentially slowing the progress of scholarly knowledge.

This presents two challenges: firstly methodological, given the identified need in this research to understand the innovation ecosystem, as the context influencing the innovators. Secondly, the lack of an accepted approach to their study means that innovator firms are unlikely to have well developed approaches to understand their ecosystem. This presents a both method and practice gap, which will be further addressed in Chapters 3 and 4. The need to understand the ecosystem and the actors within it point to two related fields of literature, a 'social' perspective (Cropanzano and Mitchell, 2005; Liebeskind et al., 1996; Luhmann, 1984; Parsons, 1951; Tsai and Ghoshal, 1998) and a 'stakeholder' perspective (Freeman, 1984), which collectively support a more 'systemic' approach (Midgley and Lindhult, 2017).

Taking a 'social' perspective, an organisation's human and financial capital, the impact of entrepreneurship, the network patterns and configuration can all have an impact on convergence (Phillips and Su, 2009). Lee et al. (2010) exploring convergence from multiple perspectives (or levels) identified not just products and technologies but also organizational innovation and infrastructure changes, therefore requiring new alliances. Different alliances need different capabilities as different types of partners connect (Rikkiev and Mäkinen, 2013; Rothaermel and Deeds, 2006), the size and capability of partners (such as SMEs) in any alliance is another potential factor (Dickson et al., 2006). Hacklin et al. (2013), identified the 'disciplinary' distance between a firm's own knowledge and other integration knowledge as key, although other studies (Enkel and Gassmann, 2010) question this. The integration challenge lies mainly in individual or group-level learning (Rikkiev and Mäkinen, 2013), as actors seek to understand and assimilate diverse knowledge, via their absorptive capacity (Cohen and Levinthal, 1990; Enkel and Heil, 2014b). The cultural challenges in convergent innovation (Dingler and Enkel, 2016) point to the need to develop social integration approaches, as well as addressing the technology. But not all interactions need to result in integration, many are simply about understanding the position of others, as stakeholders (Freeman, 1984). The cumulative implications of these 'social' challenges suggests the need to take a more *relational* perspective (Dyer and Kale, 2007).

Stakeholder management is not a new field of inquiry, with origins traced to 'systems' work at SRI in the early 1960s (Freeman, 1984). However the application can be identified as early as the 1930s through the work of Professor E M Dodd with executives at General Electric (Preston and Sapienza, 1990, p. 362). Stakeholder theory is rooted in systems theory (Ackoff, 1974; Freeman and McVea, 2001). Freeman's seminal work (1984) and later works (Freeman et al., 2010; Freeman and McVea, 2001) provide a broad description of the theory, its implications and applications. Stakeholders are often defined as '*primary*' (including the immediate value chain of suppliers, employees and customers) and '*secondary*' (which includes government, competitors, media and interest groups) (Freeman, 1984, p. 25). Mitchell and workers summarise the main formative literature and definitions of stakeholders (Mitchell et al., 1997, pp. 860–862), with a generally accepted definition as: "*an individual or group who can affect or is affected by the achievement of the organization's objectives*" (Freeman, 1984). Mitchell further proposes a typology or scoring system to categorise stakeholders based upon three attributes: 'power', 'legitimacy' and 'urgency' (1997, pp. 874–879). Much stakeholder literature distinguishes between those who affect and who are affected by a decision or action. This concept is summarised in the power (influence) and interest model (Ackermann and Eden, 2011, p. 183) now commonly used to segment stakeholder groups (Mainardes et al., 2012; Reed et al., 2009). So, understanding these would appear to be an important step in the innovation approach.

The nature of interdependence influences the stakeholders' strategies (Frooman, 2002), being determined by whether the network is unfamiliar or stable. Rowley (1997) considers the nature (density) of the network and the position of the focal firm (centrality) as influencing factors. Ackermann mapped interactions, a 'stakeholder management web' (2011, p. 189), to understand the needs of stakeholders and how these were met at three levels: rational (whole organization), process, and transactional. Much stakeholder analysis is static, but in reality evolves (Rowley, 1997). Prior literature suggests that stakeholder interests need to be balanced over time, "*it is more important to invest in long-term interactions, than to rely on a series of potentially unrelated, one-time exchanges*" (Zinkhan, 2002, p. 5). But in nascent or emergent ecosystems key stakeholders may not be immediate (Maignan et al., 2005). More recent approaches to stakeholder theory focus on the '*jointness*' of stakeholder interests rather than trade-offs (Freeman et al., 2010). Stakeholders themselves collaborate, leading to additional complexity (Savage et al., 2010). However, insights from complexity theory suggest that the most connected agents are often not the most influential (Quax et al., 2013), which may appear counterintuitive, and that a key determinant of influence was more about the susceptibility and structure of the influence network (Watts and Dodds, 2007). This would suggest that the quality of the interactions is more potentially important than the quantity of interactions, reinforcing the argument for the importance of a *relational* perspective.

Interestingly, whilst relationships and stakeholders are often mentioned in value chain and business model literature, analysis rarely goes beyond acknowledging they exist (for examples, see Baden-Fuller and Morgan, 2010; Fine and Simchi-Levi, 2010; Gardner and Cooper, 2003; Gereffi, 2011; Srai, 2007; Zott and Amit, 2010) and, as such, has not formed a significant component of recent business model or value network analysis. There has been some assessment of stakeholders, to the level of classification into 'primary' and 'secondary', but no further (Harrington and Srai, n.d.; Kumar et al., 2013). This represents a gap in the literature for both value networks and ecosystems.

A conclusion is that a better articulation of the 'how', i.e. the processes and the relationships or stakeholder influences, and explicitly defining and mapping these may provide a more coherent link to the wider ecosystem and aid understanding of causality in convergent innovation.

2.4 Developing Organisational Capabilities

The success of organisations is based upon understanding factors external to the company (e.g. the environment or ecosystem) *and* the internal factors or organizational capabilities (Porter, 1998). Considering the previously discussed challenges three aspects of capabilities appear relevant, namely: innovation capabilities, the formation of value networks, and the broader organisational capabilities needed to address the changes required for convergent innovation.

Traditional, neoclassical, economic theories draw upon transaction cost economics to determine firm boundaries (Williamson, 1985), but convergence requires not only efficiency and transaction cost considerations, it also impacts complementary assets to advance and commercialise new technologies (Rikkiev and Mäkinen, 2013). A resource based approach (Barney, 1991; Grant, 1996; Penrose, 1996; Prahalad and Hamel, 1990; Teece et al., 1997), building on a knowledge and capability perspective, identifies collaboration as essential to gain access to external resources, and as such, may provide a stronger basis to consider convergence. The success of each actor or member is "*influenced by the .... ecosystem*", as *"a holistic, intertwined entity that is in continuous evolution*" (Iansiti and Levien, 2004). Thus, reinforcing a need to address the ecosystem, the business models and the value networks, in order to understand the implications for decisions and organisation capabilities.

The resource based view (Barney, 1991, 2001, 1999; Collis, 1994; Grant, 1991; Wernerfelt, 1984) holds that the key to a firm's competitive advantage is the possession of valuable, rare, inimitable, and non-substitutable (VRIN) capabilities (Barney, 1991; Eisenhardt and Martin, 2000) and confer competitive advantage to firms either through superior product or service offerings (Porter, 1996) or via production performance or efficiency (Womack et al., 1990). The concept of '*core competencies*' (Hamel et al., 1989; Prahalad and Hamel, 1990), a revisiting of the resource based view, popularised such concepts within management, perceived easier for executives to consider, being controllable, unlike the external environment (Eisenhardt and Martin, 2000). The creation of 'core capabilities', through path-dependent learning can however become a 'rigidity' (Leonard-Barton, 1992). It is argued that these can be overcome by possessing '*dynamic capabilities*' (Teece et al., 1997). These contrast with ordinary or 'operational' capabilities (Winter, 2003), and are employed by the firm to create new capabilities. Teece, Pisano and Shuen (1997) identified dynamic capabilities as "*the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments"* (1997, p. 516). Subsequent authors (for example, Easterby-Smith et al., 2009; Eisenhardt and Martin, 2000; Helfat and Peteraf, 2003; Pandza and Thorpe, 2009; Teece, 2007; Winter, 2003; Zollo and Winter, 2002) have addressed questions such as: what constitutes such abilities, their attributes and where they come from?

The dynamic capability perspective suggests that existent organisational routines for innovation could be deployed to create something radically new (di Stefano et al., 2014; Teece, 2012). In this case, an incumbent firm requires ambidextrous structures (Gupta et al., 2007; Tushman and Reilly, 1996) and appropriate social practices to balance exploitative and exploratory innovation (Fagiolo and Dosi, 2003). If exploratory new product development capabilities (Brown and Eisenhardt, 1997) are embedded in processes of experiential learning (Zollo and Winter, 2002) within an incumbent firm, then it is possible to argue that it could develop a disruptive convergent technology without changes in organizational capabilities. An incumbent must confront technological and market uncertainties, but would unambiguously know *how* to act when developing the innovation.

An alternative argument however, suggests that advances in technology almost inevitably trigger requirements for incumbents not only to innovate their products, but to change *how* they organize for innovation (Dougherty, 1992; Dougherty and Dunne, 2011; Greve and Taylor, 2000; Yoo, 2013). Moreover, scholars assert that existing organizational capabilities more likely act as core rigidities (Leonard-Barton, 1992) by supporting cognitive inertia of relevant decision makers (Bettis and Prahalad, 1995; Danneels, 2011; Tripsas and Gavetti, 2000). This potentially obstructs internal acceptance of potentially disruptive convergent innovation at an incumbent firm. This line of argument therefore suggests it is highly unlikely for an incumbent firm to develop a convergent and potentially disruptive technology without changes in its underlying organizational routines and capability for innovation.

This sharp dichotomy between sustaining existing organizational routines for innovation versus developing entirely new ones leads to two sharply different implications for managers at incumbent companies. They should either replicate (Szulanski, 1996; Winter and Szulanski, 2001) existing organizational routines and learn 'as they go', or radically depart from the existing ways of how they innovate. So, a more nuanced and subtle understanding of change in organizational capability for convergent and potentially disruptive innovation would be relevant for both innovation theory and practice. An implication of this is that understanding 'why' processes are employed is as important, and relevant, as understanding 'which' processes are employed, and 'how'.

2.5 Innovation Management

Innovation has been the focus of extensive research (Fagerberg et al., 2012) with much of that focus being on the innovation system or on organizing innovation. Smith et al. (2008) conducted a systematic literature review of innovation identifying nine important factors that impact on an organisation's ability to manage innovation, and concluded that the *innovation process* is a key factor to which all other factors impact. A further systematic review by Crossan and Apaydin (2010) developed a framework to delineate the 'determinants of innovation' (e.g., leadership, organisation and business processes) from the 'dimensions of innovation' (e.g. innovation as a process and as an outcome), concluding that innovation as a process (i.e., how?) is under-developed in the literature. Montoya-Weiss (1994) and Holahan (2014) identified 'best practices', with the emphasis being in organising innovation. However, much of this literature has focused on innovation by incumbents in existing industries.

Innovation and new product development processes are often considered as sequential, with 'stage-gates' (Cooper, 1990) reinforcing linearity, but in reality they are 'messy', 'improvised' and experimental (Garud et al., 2013, p. 787), especially at the early stages (and as later acknowledged by Cooper (2008)). New product development (NPD) and innovation processes may be considered as complex adaptive systems (Frenken, 2000; McCarthy et al., 2006). This is echoed by Anderson and Joglekar (2012) who describes a systems approach to managing innovation. More recent work on '*open innovation*' (Chesbrough, 2003; Chesbrough and Teece, 1996; Gassmann et al., 2010a) further increases system complexity as the number of agents and interdependencies increase. However, it appears that many firms still operate 'linear' processes

(Browning and Ramasesh, 2009; Sommer et al., 2014, p. 980). Within health care this perceived linearity is further reinforced by regulation (FDA, 2014a, 2014b; Food and Drug Administration, 2013; Medicines and Healthcare Products Regulatory Agency, 2003).

This would suggest that incumbent firms will need to break with traditional innovation approaches and develop new organisational capabilities. The specific implications for the innovation processes will be addressed later in this chapter.

2.5.1 Cognitive capabilities

Whilst innovations are often likely to be technology driven, the assessment of them is not an 'objective' phenomenon, but a socio-cognitive process (Garud and Ahlstrom, 1997) with "*differences in foci and sense making approaches, differences in epistemologies, and differences in criteria for evaluation*", which innovating firms need to address in their interactions with stakeholders and potential customers (this point is further discussed in the section on business models and value). Taking the subject of stakeholder and customer interaction further, Von Hippel (von Hippel, 2009, 1988) and Awa (2012, 2010) both call for a 'democratizing' of the innovation process, with greater customer co-development and links to 'user groups' for testing and feedback. Aligned with this, there is a trade-off between enhancing trust (in the user group) versus reducing risk (of not meeting expected performance) when developing a new product (Nienaber and Schewe, 2014), calling for greater contact intensity and relationship commitment. The influence of strategic partners (as part of the emerging value network) on innovation, has also been shown to be an important factor (Bröring and Leker, 2007). In conditions of convergence those partners are likely to be harder to find and have different norms in terms of capabilities and culture (Dingler and Enkel, 2016).

In convergence, knowledge distance between partners is implicit. Knowledge management is considered an important antecedent to innovation (Moos et al., 2013). Fundamental to knowledge management is a firm's absorptive capacity (Cohen and Levinthal, 1990). The innovation literature identifies strong links between knowledge management and the need for absorptive capacity (Cohen and Levinthal, 1990; Enkel and Heil, 2014b; Gauch and Blind, 2014; Moos et al., 2013). But given the implied knowledge distance there is also a need to exchange that knowledge between groups and individuals with different knowledge bases, suggesting that any such exchange will require the use of 'boundary objects' (Leigh Star and Griesemer, 1989) and a means to either 'transfer, translate or transform' (Carlile, 2004, 2002) that knowledge. Investigating knowledge transfer effectiveness, Argote and Ingram (2000) identified that to be effective, information needs to be well codified and that a large number of weak ties (Grannovetter, 1973; Granovetter, 1983) are important to provide the ability to search, identify and acquire knowledge. However, where knowledge may be poorly codified, as in convergence, then strong ties and repeated interaction may be equally important. This suggests that the nature of the relationships and information exchanges within the innovators network could be highly influential.

2.5.2 Innovation processes

As previously identified, the innovation processes have had limited research (Crossan and Apaydin, 2010; Garud et al., 2013). In part this may be due to difficulty in studying innovation processes in action, as much research captures data after the event. Furthermore, complexities in studying them also arise, as Garud et al. (2013) point out: innovation processes are: (a) co-evolutionary, as they simultaneously implicate multiple levels of analyses (Murmann, 2003); (b) relational, as they involve a diverse set of social actors (Bijker et al., 1987); (c) inter-temporal, as temporal events and sequences are experienced in multiple ways (Garud and Gehman, 2012); and (d) cultural (Dooley and Van de Ven, 1999), as they unfold within different contexts. Where processes have been reviewed (Browning and Ramasesh, 2009; Cooper, 2008; Cooper and Kleinschmidt, 1995), they identified various process model 'types' used, variously described as: linear; "spiral"; concurrent; networked and "vee". Many prior reviews focus on 'actions' rather than 'interactions' (Browning and Ramasesh, 2009), further suggesting that prior research has underplayed the more contextual and relational elements involved in innovation.

Convergent innovations, whilst incremental in one industry, may be disruptive in others (Enkel and Gassmann, 2010). Veryzer (1998) identified that disruptive innovations were less reliant on a formal process. Similarly, Bessant et al. (2005) exploring differences in innovation capabilities and approaches for 'steady-state' versus 'discontinuous' innovations identified that: there are no clear rules by which actors play; there needs to be a high tolerance for ambiguity; there is no clear trajectory; that routines are open ended, based around managing emergence. They concluded by suggesting that developing 'fuzzy front end' type approaches (Koen et al., 2001) may be beneficial.

Koen, in a number of studies (Koen et al., 2014, 2001, 1996) identified several approaches to the 'fuzzy front end', or 'front end innovation'. These were seen to differ from traditional innovation perspectives (e.g., Cooper, 1990), with opportunity identification and analysis, idea genesis and selection and, the concept and technology development being core to innovation capability. More importantly the 'fuzziness' implied is considered inappropriate, being better described as 'front end innovation'. It also suggests that processes are likely to be context specific. Koen et al also identify key capabilities for organisations focussed on senior management commitment, vision and strategy and culture, rather than processes (Koen et al., 2014). This role in providing governance and in making strategic decisions is now considered.

2.6 Governance and investment decisions

The influence of senior management on new innovation processes is important, primarily as 'gate-keepers' (Cooper, 2008, 1990; Cooper and Kleinschmidt, 1995) but also in other ways, such as learning and knowledge management (Gomes et al., 2001). The success of the venture depends upon sponsorship of top management and developing a supportive internal 'ecosystem' (Girotra and Netessine, 2014).

Investment decisions in situations with high uncertainty and risk carry an increased risk of bias (and potential failure) as a consequence of *representativeness* (misconceptions, particularly where relationships are non-linear), *availability* (impacted by the ease of retrievability, and illusory correlations) and *adjustment and anchoring*, as a result of insufficient analysis and objectivity (Kahneman and Tversky, 2007; Kahnemann et al., 1982). Convergent innovation is characterised by higher uncertainty (absence of knowledge) and higher equivocality (multiple, ambiguous and sometimes conflicting sources of knowledge) (Daft and Lengel, 1986), so, the use of multiple and alternative perspectives, and building pluralism in the decision making is likely to be important (Allen, 2001).

Considering other types of innovation, '*open innovation'* (H. Chesbrough, 2006; Faems, 2008) decision gates require modified criteria (Gronlund et al., 2010) to ensure external know-how, paths and capabilities are continually assessed. Convergent innovation could be considered an extension of the open innovation concept, but spanning industry and technology boundaries. A similar concept is 'co-innovation' (Lee et al., 2012) which is built upon ' *… principles of convergence of ideas, collaborative arrangement, and co-creation of experience with stakeholders*' (Lee et al., 2012). Both suggest the increased importance of external know-how, pluralism and stakeholder input. A further challenge is that the innovation is not autonomous (Dosi et al., 1998; Nelson, 1998), in healthcare there may be wider effects, particularly in downstream care pathways. This suggest a more systemic approach to innovation (Teece, 1996) is needed for integration of the innovation into the adoption chain (Adner, 2012, 2006). This systemic intervention (Midgley, 2014, 2006) or systemic innovation (Midgley and Lindhult, 2017) suggests that innovators need to pay attention to both the upstream and downstream stakeholders and value chains and develop approaches to utilize systems thinking to embrace complexity (Garud et al., 2013).

Convergent innovation also requires integration (Rikkiev and Mäkinen, 2013), but integrated product development (Gerwin and Barrowman, 2002), managing the overlapping, parallel execution and concurrent workflow of activities (Gerwin and Barrowman, 2002) brings further challenges for governance and senior management (Sommer et al., 2014), driven by the increased complexity and ambiguity. The risks include technical, management and market elements (Zhang and Yongbo, 2011), determined by innovative and technological uncertainty, resource uncertainty, and consumer and competitive uncertainty (Moenaert and Souder, 1990). In convergent innovation additional risks may exist in integrating across alliance partners (Rikkiev and Mäkinen, 2013). The ability to manage across these different risk types would therefore be expected to be a key capability in firms developing convergent healthcare technology innovations.

2.7 Developing Alliances and Value Networks

Developing innovation, especially under conditions of convergence, with diverse technologies, requires the formation of alliances (Doz, 1996; Li et al., 2008); defined here, as by Kale et al. (2002, p. 748) as '*any independently initiated inter-firm link that involves co-development, sharing or exchanges'*. The alliances provide the basis for resource heterogeneity (Penrose, 1959; Wernerfelt, 1984) with the unique combination providing the possibility to create and capture value. They could be considered as enabling an *extended enterprise* model (Gulati et al., 2012) where a focal firm (or group of firms) contracts with upstream, downstream, or horizontal partners that possess complementary assets (Rothaermel, 2001) to enhance their own technology, capabilities, or market reach. Specifically, Sebastio and Golicic (2008) argue the case that the successful emergence of a new market, based on a 'radical technological' intervention, depends largely on the parallel development of a new value network to support commercialization activities. Adner (2012) extends these requirements beyond the value network itself to consider the wider 'adoption chain' necessary to commercialize the innovation and, hence, capture value. These activities can be considered as market creating, using a *constructionist* approach (Jaworski et al., 2000) as partners seek to complement knowledge and capabilities to create value (Lepak et al., 2007). It is not sufficient to just innovate a product or develop a value network, it is also necessary to construct markets and navigate institutions, which requires collective entrepreneurial action (Santos and Eisenhardt, 2004, 2009) and, a process of exploration to effect a transformation, or 'effectuation' (Sarasvathy and Dew, 2005) amongst multiple alliances.

In order to profit from such cross-industry collaborations, innovators must be able to find, and then transfer knowledge with their cross-industry partners (Gilsing and Nooteboom, 2006; Zahra and George, 2002) and then create new organizational boundaries (Santos and Eisenhardt, 2005) as they form value networks to deliver the innovations to customers (Harrington & Srai 2016). Firms create alliances to address strategic needs and social opportunities (Eisenhardt and Schoonhoven, 1996), but despite their attractiveness alliances can have high transaction costs (Williamson, 1999), may present routes for 'leakage' of core competencies (Hamel et al., 1989) and may reduce profit or revenue streams (Eisenhardt and Schoonhoven, 1996). Alliances can fail due to poor partner selection (Hitt et al., 2000) or poor management (Ireland, 2002).

An organisations structure, as previously noted, is also impacted by product modularity (Baldwin and Clark, 1997). One can distinguish between decoupled, loosely coupled and tightly coupled systems (Brusoni et al., 2001). Modularization reduces uncertainty and complexity helping to identify problem and solution paths, enhancing learning processes (Tyre and Hippel, 1997) and improving knowledge predictability (Chesbrough and Teece, 1996; Sanchez, 2002). Product modularization shapes the vertical division of labour, which favours knowledge specialization and creates boundaries (Baldwin and Clark, 2000; Langlois and Roberston, 1992; Sanchez and Mahoney, 1996; Schilling, 2000). Consequently, firms often align knowledge boundaries with production boundaries (Dibiaggio, 2007). Value chains fragment at those points where knowledge is *most explicit and codified*, which also determines the form of economic governance (Gereffi et al., 2005). Although activities can be divided between specialist firms, in convergence 'systems integrators' must develop knowledge outside the scope of their 'productive activities' (Patel and Pavitt, 1994) and integrate knowledge from different sources (Brusoni et al., 2001; Hobday et al., 2005).

The concept of value network integration or re-integration has been less explored; but Cacciatori (2005) noted that reintegration may occur when the limitations of specialization are reached and new customers services are demanded. Funk (2012) explored the relationship between vertical disintegration and entrepreneurial opportunities, identifying that those opportunities arose at the '*interstices',* challenging conventional wisdom about '*dominant designs'*, identifying that niche opportunities, like those offered by open interface standards, enabling late entrants to 'win'. Davies (2005; 2004) examined integration to provide high-value services to address customer-centric solutions, as may be required in health care. But by definition, in convergent innovation and a nascent or emerging innovation ecosystem, no dominant design exists. So, innovators have many options, paths and investment challenges and much of the extant literature on value network formation is rooted in incumbent firms and established industries (for examples, see Eisenhardt and Schoonhoven, 1996; Gulati, 1999; Lavie and Rosenkopf, 2006).

As convergence requires new capabilities (Enkel and Heil, 2014b) the organization has a number of options for acquiring or accessing these (Barney, 1999; Gulati et al., 2012). Given the challenges in internal development or in outright acquisition, alliance formation and alliance management (Schreiner et al., 2009) under conditions of high uncertainty, would therefore appear to be a critical capability in the development of 'nascent value networks'. In organizational terms, this may be considered as the 'conception and development' stage (Kazanjian and Drazin, 1990), either as a new venture (start-up) or as a new business unit within an incumbent firm. Harrington and Srai (2016) describe the stages of emergence of value networks and their characteristics, the network stages and transitions from 'embryonic' to 'fragmented' to 'formation' being the most relevant to the study of nascent value networks. A factor influencing the formation is the extent to which the networks or alliances are formed as a result of an emergent process or engineered, via a dominant player (Doz et al., 2000).

Kale and Singh (2007) identified that an alliance learning process involving articulation, codification, sharing, and internalization (Cohen and Levinthal, 1990; Zahra and George, 2002) of alliance management know-how is positively related to a firm's overall alliance success, these alliance capabilities being described as 'higher-order dynamic capabilities'. That research however, focused solely on large established companies in existing industries. In the context of the formation of value networks in nascent ecosystems, they can also be considered as the quadrant of 'pre-formation value creation' (Wang and Rajagopalan, 2015) and that a competence based approach (considering information search, codified routines and partner evaluation) may be appropriate. Draulans et al. (2003) recognizing that most alliances fail, looked at capabilities for alliance success in inexperienced and established firms, concluding that learning processes are important, but only up to a point, and that inexperienced companies can benefit from training or the use of alliance experts and that the type of alliances and their diversity can also influence outcomes. This would suggest that context, i.e. the nature of the ecosystem is an important consideration. However, as identified by Stuart and Sorenson (2007), extant research focuses disproportionately on the consequence of the network (or ecosystem), rather than its origins (i.e. how they built it).

The crucial role of relational capabilities in developing and managing alliances has been demonstrated in the literature (Ireland et al., 2002). For example, prior research suggests that a firms negotiating capability (Simonin, 1997) and its governance capability (Aggarwal and Hsu, 2009) are strong determinants of alliance success. Similarly, Arikan (2009) identifies a number of failure modes for knowledge exchange, largely driven by the firm's capability and the opportunities (in terms of number and quality) for knowledge exchange. Taking a relational perspective, the role of relationship specific investments, knowledge-sharing, complementary capabilities and effective governance (Dyer and Singh, 1998) are seen as determinants of inter-organizational competitive advantage in the context of an evolving network (or ecosystem). A relational view of governance is typically underpinned by social exchange theory (e.g. Blau 1964), highlighting the role of relational norms, trust and control in social exchange.

Knowing the key stakeholders within an emerging ecosystem, and conversely being known within it, is critical in order to foster effective cooperation across the entire value network (Harrington & Srai 2016). Classical stakeholder management (Freeman, 1984) would stress identifying all the stakeholders as a first step and then addressing issues of power and influence. However stakeholder salience is highly dependent on the innovators position within the ecosystem (Frow and Payne, 2011). In emergent ecosystems, key stakeholders may not be immediate (Maignan et al., 2005), and so identification needs to be a continual exploration, with iteration and refinement. Making connections and then making sense of these connections and their potential contribution (Sutcliffe et al., 2005; Weick et al., 2012) points to heuristics, with experimentation and learning (Bingham and Eisenhardt, 2011).

A major issue, yet to be explored, is how firms can build these capabilities and ensure they are developed in a complex evolving environment (Donada et al., 2016; Dyer and Kale, 2007). Much of the extant value network literature focuses on existing and established value networks (for examples, see Choi & Hong 2002; Srai & Gregory 2008), identifying ways to optimize, control (Lee, 2002) or govern these (Gereffi et al., 2005). There is limited literature on the formation of nascent and emerging value networks (Sebastiao and Golicic, 2008). Recent research points to *relational capabilities* being more important than internally focused capabilities (Brinckmann and Hoegl, 2011) as these are key to enabling the innovator to access wider resources and capabilities. Furthermore, the capabilities required to co-create with multiple stakeholders, implicit in this type of innovation, have also had limited study (Kazadi et al., 2016).

In summary, what is not clear are the key relational capabilities and underpinning routines needed to successfully effect the development of the innovation, to form the required alliances (with multiple co-creators) and value network in a nascent ecosystem. A further compounding issue is that such capabilities may be influenced by external and/or internal factors (Doz et al., 2000), which has not been addressed explicitly in empirical research (Eriksson, 2014).

2.8 Business Modelling

A general problem with any 'capabilities approach', as noted by Bowman and Ambrosini (2000), is that 'neo-classical' resource based approaches do not explain value creation and capture and this represents theoretical gap. This was later reiterated by Priem (2007) who did not consider any of the firm positioning (Porter, 1980), transaction cost (Williamson, 1998) or resource based views (Barney, 1991) as adequately capturing the demand needs and value capture, but instead focuses on 'how a focal firm as a member of a value system can increase its share of consumer payments to that system, at the expense of other members, in a zero sum game'. Markides (2006) identifies distinct differences between technology, product and business model innovation, but notes that recent literature have tended to treat this as one. Consistent with this view, the implications of business models and business model innovation are now considered.

In the past fifteen years, there has been growing interest in the 'business model' concept (Al-Debei and Avison, 2010). Interest accelerated with the advent of e-business, which required models that could not adequately be expressed by classical strategy and value chain models (Amit and Zott, 2001). Early research was in e-business (Zott et al., 2011), however, the approaches are now more broadly accepted (DaSilva and Trkman, 2013; Johnson et al., 2008; Osterwalder and Pigneur, 2013; Shafer et al., 2005; Zott and Amit, 2013).

Definitions of business models are ambiguous (DaSilva and Trkman, 2013), lacking 'paradigmatic neatness' (Smart et al., 2016), but in most studies they are seen as an attempt to address the gap between strategy and execution, by recognising that conventional resource based views do not explicitly explain value creation and capture (Baden-Fuller, 2014). Business models have been seen: as a means to ensure sustainability and performance (Afuah and Tucci, 2000; Bocken et al., 2014; Funk, 2003); to define the important linkages between critical capabilities and business components; to ensure balanced resources (Achtenhagen et al., 2013); to describe "*as a system*" how a business fits together (Magretta, 2002); and to identify the need for firms to have knowledge beyond their boundaries and current product offering (Brusoni et al., 2001).

Essentially, business model literature is split between seeing business models as *descriptors* of a business and its strategy, those who see business models as a *model* of the business and those who see business models as *mediating devices*. Consequently, there is no agreed taxonomy for business models (Baden-Fuller and Mangematin, 2015a). However, they provide the potential to link the innovation, the ecosystem and the value network capabilities, and thus are potentially important to this research.

A significant body of the literature treats business models as 'descriptors' with the terms 'business model' and 'strategy' often used interchangeably. Others attempt to encompass all business activities into a single 'model' (H. W. Chesbrough, 2006; Johnson et al., 2008; Osterwalder et al., 2010; Petrovic et al., 2001; Rajala and Westerlund, 2007).
Chesbrough (2010; 2002) identifies six functions in a business model: the value proposition, the target market segment, revenue sources, the value chain and complementary assets, the position of the firm in the value network, the cost structure and profit potential. Presented as '*descriptions of the logic of the business system'*, Petrovic et al (2001) divides a business into seven sub-elements, thereby attempting to encompass all of the business into a single 'model'. Johnson and Christensen (2008) take a simpler approach, defining the business model as: customer value proposition, a profit formula, the key resources and key processes, but extend the concept to describe supply chain and value chain activities. Osterwalder and Pigneur (2010) developed a design framework that is much used in practice, and can be viewed as a series of nine elements: value proposition, client relationships, client segments, distribution channels, partner network, key activities, key resources, and finally, cost structure and revenue flows. However, the framework infers design is possible, which may not be the case if the information is diffuse and outcome ambiguous. It has also been identified as a static tool and not addressing the dynamics of business model innovation or evolution (Eurich et al., 2014). More recently approaches have been developed to visualise each 'design' snapshot as part of an evolution (Fritscher and Pigneur, 2014).

Baden-Fuller and Morgan (2010), identify a business model as a 'model', and provide a summary of different models, arguing that the explicit link with technological innovation as providing '*a more holistic view of a business model*' that is seen as a 'system' that defines customers, engaging with their needs, delivering satisfaction and monetizing value. In essence, the model defines a cause and effect relationship (Baden-Fuller and Haefliger, 2013). Business models maybe 'conceptual' rather than 'financial' (David J. Teece, 2010), but they create value, entice payments and convert payment to profits, by identifying choices.

Much of the extant literature takes an essentialist view of the business model as a description or representation. A business model can also be considered as a cognitive agenda (Baden-Fuller and Mangematin, 2013) by treating them as categorical models built upon causal models, using a typology of: customers, customer engagement, monetization and value chain and linking mechanisms. In so doing, "*business models are 'manipulable instruments' which can be used to explore cause and effect and understand the world of business better*" (Baden-Fuller and Mangematin, 2013, p. 424). In a similar vein a business model can be considered as a 'market device' (Doganova and Eyquem-Renault, 2009). Some authors (Eppler et al., 2011; Velu, 2015) have conceptualised them as 'boundary objects' (Carlile, 2002; Leigh Star and Griesemer, 1989) enabling interchange between stakeholders. As a market device, Margetta (2002) identifies two key components for a business model: the narrative (the story or value proposition) and the numbers (the economics). A market device infers that business models are developed through a trial and error process (Sosna et al., 2010), rather than designed. This approach is consistent with McGrath's view (2010) that the creation of a business model requires an 'outside in' and experimental discovery approach.

2.8.1 Business models as systems

Zott and Amit have undertaken considerable research on business models (Amit and Zott, 2012, 2001; Zott et al., 2011; Zott and Amit, 2013, 2010, 2008, 2007), describing recent developments as a "*holistic-system level approach*" that is now theoretically anchored and address the challenge of unresolved overlaps with other theories, which can be used as a unit of analysis. Their model is described as an "*activity system"* (Siggelkow and Porter, 2008) with a set of interdependent organizational activities centred on the focal firm, using four 'design themes' to create value: novelty, lock-in, complementarities and efficiency, and recognise that more than one theme can exist within a firm's model. Richardson (2008) also takes an integrative approach using a wide range of literature to derive common elements that "*can be seen as the conceptual and architectural implementation of a business strategy and as the foundation for the implementation of business processes*". Using marketing-like approaches (Kapferer, 2004; Kotler, 2003) the model, aiming for "*a simplified logical structure",* is defined by: the value proposition, how value is created and then captured. These core elements are common themes, however various authors elaborate adding elements, extending into capabilities or the value chain (Figure 2-2).

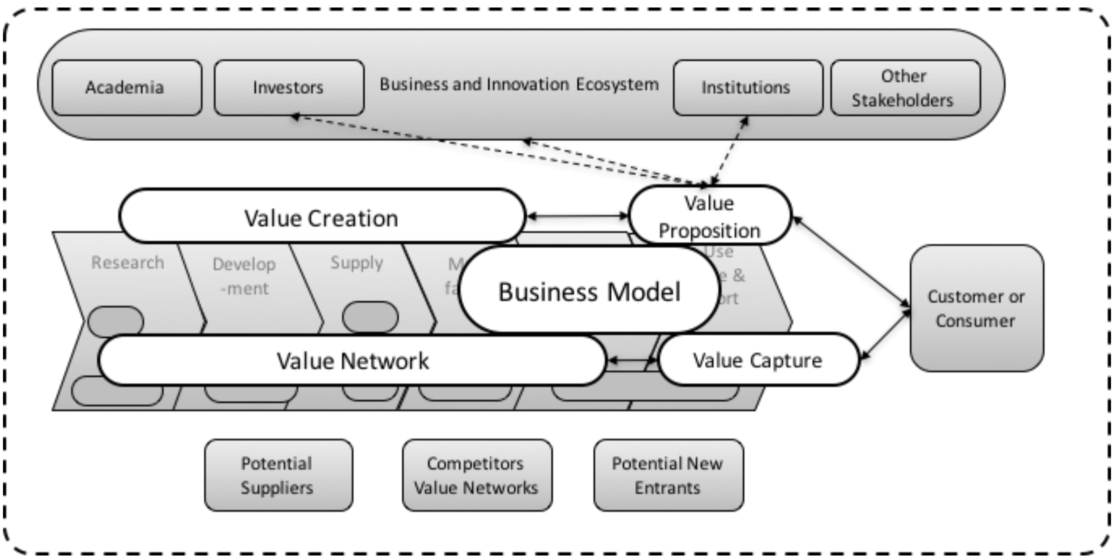

Figure 2-2 Business model concept (derived from Richardson, 2008)

The notion of a business model is that it represents '*an extension of the value chain idea*' (Zott and Amit, 2013). It can therefore be consistent with the resource based view and value networks from a philosophical perspective. It has also been argued that a business model is a standalone concept because it is a 'model' (Baden-Fuller and Haefliger, 2013) and the extent and complexity of that 'model' is a major strand of recent research (Andersson et al., 2006; Zott et al., 2011). Business models are not static, but evolve (Demil and Lecocq, 2010). However, Sosna (2010) identified that there is limited literature on their evolution, representing another literature gap.

2.8.2 Value, Creation and Capture

In the analysis of business models, the concept of 'value', its creation and capture are constant themes. Until recently there has been little agreement about what is 'value' (Bowman and Ambrosini, 2010, 2000; Lepak et al., 2007; Makadok and Coff, 2002; Priem, 2007). Bowman and Ambrosini (2010) suggested that a prime cause was that 'value' means different things to different people. To resolve this, 'value' has been defined (Bowman and Ambrosini, 2000; Lepak et al., 2007) in terms of 'value creation' and 'value capture' and between 'use value' (UV) and 'exchange value' (EV). The 'use value' can be considered akin to marketing's 'customer-perceived value' (Kotler, 2003, pp. 418–426), which results from the prospective customer's evaluation of all benefits and costs of the offering or alternatives (Treacy and Wiersema, 1997). Lepak (2007) introduced the concept of '*value slippage'*, the difference between a firm's value creation and what it receives in capture. The 'slippage' being ascribed to the combined effect of competition and the countering '*isolating mechanism'*, which provides knowledge, physical or legal barriers to prevent replication of the product or service. Priem (2007) identifies the concept of 'consumer benefit experienced', as alternative viewpoint on value, such that value creation is only a pre-condition for value capture. Importantly Lepak (2007) identifies that value creation and capture can occur and transfer across the hierarchy of society, organisation and individual, so it has multi-level properties and potential utility in healthcare settings where benefits may be ascribed at different levels (Di Gregorio, 2013).

The concept of using integrated models that address the value build up, dynamics and exchange were proposed by Khalifa (2004). Allee (2008, 2000) used a value 'network analysis' to address intangible assets, identifying that they may be converted to monetary value or a negotiable form of value. During the development of a product, the asset is often intangible (Teece, 2010), until it can be 'converted' or 'enhanced' to 'recipient perceived value' or its wider 'societal value'. This suggests an evolutionary or lifecycle approach, with the potential value proposition as a device to link to key stakeholders in the ecosystem, and to the ultimate customers and consumers.

Returning to the challenge of the innovation, Rogers (Rogers, 2003) suggests a model of innovation diffusion. This model of *diffusion* has five significant elements: an *innovation*, which is *communicated* through certain *channels* over *time* by members of a *social system* (*emphasis* in original). So, rather than a description, design or model, the concept of business model evolution, or 'business modelling', especially in a nascent ecosystem represents a potentially important concept. Considering the act of business modelling, as a dynamic process, rather than a design or one-off event, is considered next.

2.8.3 Business modelling (as an activity or process)

Baden-Fuller and Mangematin (2015a) took a process perspective identify a consider strategizing, modelling and enacting business models. Fundamental to the business model concept is a resolution of the questions "Who is the customer?", "What value is created?" and "How is that monetized?" (Teece, 2010). As identified early, during the early phases of the innovation, the asset may be intangible, but also the actual customers and how it is monetized may also be opaque, resulting in challenges due to uncertainty, ambiguity, lack of knowledge and skills (Cavalcante et al., 2011; Chesbrough, 2010; Doganova and Eyquem-Renault, 2009). This may be addressed by a trial and error process (Sosna et al., 2010), but to do this requires innovators to conduct an 'experiment' and obtain data. This may be achieved through an information pooling process (Eppler et al., 2011), enabling knowledge to cross *epistemic boundaries* (Gavetti and Levinthal, 2000). Taking the business model as 'boundary object' (Eppler et al., 2011) provides a mechanism to engage others and conduct the experiments. A boundary object (Carlile, 2004, 2002; Leigh Star, 2010; Leigh Star and Griesemer, 1989) allow different groups to attribute different meanings (particular to their needs) to the same material or artefact. Leigh Star (1989) conceived four types of boundary object: repositories, ideal type, coincidence boundaries and standardized forms. Carlile (2004) considered their management as a process involving transferring (syntactic), translating (semantic) and transforming (pragmatic). Here it is argued that counter to Eppler et al (2011) the business model *per se* is not a suitable 'boundary object' for business modelling, however, components of it are; these being the *potential* value proposition (pVP) and the corresponding *potential* exchange value (pEV), and that these represent 'ideal type' boundary objects (Leigh Star and Griesemer, 1989) and therefore suitable and adaptable for the interchange of ideas and concepts, and of economic valuation.

The value exchange process, especially in convergence, requires boundary crossing (Akkerman and Bakker, 2011) and *polycontextuality* (Engeström et al., 1995), and therefore tends towards the need for pragmatic transformation in Carlile's (2004) model. In a different sense it represents the mechanism for co-creation (Nenonen and Storbacka, 2010) of the business model. In the transaction between these actors, the 'value exchange', provides a linking mechanism. Traditionally, this 'value exchange' has been seen as a dyadic relationship (Jacobides et al., 2006). In health care, economic evaluations are a common precursor to market access (Kobelt, 2013) and involve an analysis of outputs (benefits to patients and society) and inputs (costs and resource usage). In healthcare a triadic approach, or more, may be necessary to explain the complex nature of the value exchange between a producer, and the patient, practitioner, provider and payer. In business model terms this could be described as a 'multi-sided model' (Baden-Fuller and Mangematin, 2013), requiring different cognitive capacity from traditional customer relationship models. More importantly in business modelling terms this appears to require approaches to embrace the complexity of multi-sidedness. However it is noted that the study of business modelling, with the fairly recent field of business models, has received limited attention (Baden-Fuller and Mangematin, 2015a, 2015b).

2.9 Emerging questions and conclusions

The literature review suggests that the nature of convergent innovation requires that multiple research perspectives are taken. The literature has considered both the context (convergent technologies and nascent ecosystems) and innovation approaches (capabilities and processes, value networks and business modelling). Several potential gaps in the literature have been identified which will be further addressed in Chapter 3, to help define the research aims and objectives.

As previously noted, the empirical study of convergent innovation in healthcare technologies has received little attention to date. Given the importance of this field, this is surprising.. This leads to several method related questions:

As noted by Garud et al (2013), despite the plethora of research on 'innovation' there has been very limited research of the process and on understanding the context of agency, which talks to considering more fundamentally: "**How to study innovation processes?".** The literature suggests taking a more contemporaneous approach, with longitudinal studies and engagement with actors to better understand nuances and reasoning. This suggests in-depth case studies as the most appropriate approach, which will be discussed in the methodology chapter.

All ecosystems are dynamic and evolve. In convergence that evolution is likely to be more rapid and dynamic, resulting in highly dynamic ecosystems. Consequently, the context for any research is likely to change as the research is undertaken. Addressing this is therefore important to increase confidence in any findings and infers a need to address: "**How to study innovation in the context of a nascent and evolving ecosystem?".** Furthermore, there are acknowledged challenges in studying ecosystems in general (Oh et al., 2016; Ritala and Almpanopoulou, 2017), which will be addressed in the methodology chapter.

Thirdly, the research aims to better understand how organisations undertake innovation in this more complex and dynamic environment. The literature points to several areas where 'innovation practices' may be apparent. It is not just the 'innovation' that is being developed, but also the associated value network and the business model required and in doing so the organisation may need to develop its own organisational routines. So, a question of scope emerges: "**What aspects of innovation to study?"**

A classical approach, would suggest focussing on one aspect, for example the formation of value networks, but adopting this approach runs the risk of narrowing the potential sources of causality too much and missing important factors. Equally attempting an all embracing, holistic approach is too ambitious and risks over generalisation. It therefore requires an approach is to consider the wider implications of innovation, but also to address a range of specific sub-questions relevant to the field. For example, "**How are nascent ecosystems developed?",** "**How are value networks formed?",** and **"How are business models developed?".** Whilst these questions point to different aspects of the literature they are linked in terms of innovation approaches, and so may be linked in terms of underlying causality, and so this identifies a need to address: "**Are there links between the development of the innovation, the value network and the business model?"** and, "**Are there common sources of causality?".**

As convergence implies working with actors from different fields and the potential formation of new ecosystems, the question of: "**How organisations manage their relationships?",** emerges as potentially important as this may influence their connections, and access to knowledge and capabilities.

Innovations require organisations to make investments in the innovation itself and in supporting capabilities. Given the inherent risks associated with convergence, it would imply that investment decisions may be regarded as more risky or difficult than for other innovation, and so: "**Do innovators need to change their risk and investment management approaches?"** If they do change, how are these managed? And do they present additional challenges?

Finally, the question of "**How are these brought together**?", emerges as a final 'integrating' question. The complex nature of the emerging ecosystems, converging technologies and issues around concurrently developing the innovation, business models, value networks and capabilities result in a diverse set of challenges, for the innovator and the researcher; as well as being nascent, they are dynamic in that knowledge and actors, and institutional frameworks are also changing.

3 Research Aims and Objectives

3.1 Research Challenges and Emerging Gaps

This research aims to better understand the challenges of convergence in healthcare technologies and to identify how organisations innovate in the resulting nascent ecosystem. In so doing, this addresses identified gaps in the innovation literature (for exmaple, Garud et al., 2013) and provides empirical evidence in a field of increasing importance in practice.

This leads to the primary research question: "**How do organisations innovate in complex, highly dynamic convergent and emergent healthcare ecosystems?".**

Approaches to understanding convergence and ecosystems (Hacklin and Wallin, 2013; Rikkiev and Mäkinen, 2013) have been considered in terms of identifying product and technology trends (e.g. via road mapping) and identifying infrastructure and policy development influences (Geum et al., 2015). Recent ecosystem mapping has made progress in identifying stakeholders (Harrington and Srai, 2012; Srai et al., 2014), but does not *explicitly* address the impacts of dynamics, relationships and influence. Taking a stakeholder view, mapping linkages and influence-interest (Ackermann and Eden, 2011), together with roadmaps and other mapping approaches should substantially address this gap.

Attempts to use systems or complex systems approaches for investigation in this field to date are limited (Sull and Eisenhardt, 2012; Zahn, 1999), with a few notable exceptions (Choi et al., 2001; Choi and Dooley, 2009; Frenken, 2006; McKelvey, 1999), whilst of potential benefit, a complex systems approach has not been widely adopted in the development of approaches to address ecosystem (Oh et al., 2016; Ritala and Almpanopoulou, 2017). In order to do this it will be necessary to develop a systems-consistent methodology for the study of the wider ecosystem.

For healthcare technologies, the convergence taking place is largely 'complementarity' in nature (Rikkiev and Mäkinen, 2013). The integration of technologies from other industries has the potential to deliver disruptive change (Hacklin et al., 2010). Convergence creates challenges akin to those in front end innovation, discontinuous and disruptive innovation where knowledge is dispersed, poorly codified, needs to be translated or transformed. Given the nascent nature of the ecosystems being studied and the field in general, an exploratory approach that enables an understanding of how, and why, organisations undertake innovation activities is appropriate (Garud et al., 2013). Furthermore, innovation, as a process, has been the subject of limited empirical studies. In studying such innovation processes, the literature identifies the need to adopt an in-depth, longitudinal approach and to understand both context and agency. Again, there has been limited empirical research adopting this approach.

The value chain or value network approach might offer some insights, but there has been little research on early, or nascent, value networks (Harrington and Srai, 2016). Furthermore, value network approaches do not explicitly address the issues of value creation or capture (Bowman and Ambrosini, 2000; Zott et al., 2011; Zott and Amit, 2013, 2008), and so, provide only a partial answer.

Finally, innovation is essentially about creating and capturing value, and so by considering *business modelling* approaches a means to help integrate the innovation, value network and capabilities may be possible, thus addressing a gap in the literature and help move towards a more integrated or systemic approach.

Organisational capabilities, including those for innovation will likely change under conditions of convergence. The existing capabilities literature does not satisfactorily address the apparent dichotomy between path dependent, dynamic capability and ambidexterity arguments for how these capabilities are changed. As part of the organisational capability, there is also a need to create value networks in a rapidly evolving ecosystem, the creation of these nascent value networks has had limited empirical study to date. Therefore, understanding how and why they develop their capabilities.

The final challenge, as previously identified, is in identifying how to integrate these, to provide a more holistic perspective. Here again, taking a more systemic view of innovation provides some promising solutions.

3.2 Research Question

Taking account of the challenges in the ecosystem, the specific challenges of convergence and requirements for new product development, the main research question is:

> *RQ: How do organisations innovate in complex, highly dynamic convergent and emergent healthcare ecosystems?*

Drawing on the emerging questions and conclusions from the literature review, this research question can be further decomposed or complemented by several supplementary questions, considering specific aspects of the innovation activities, which this research will aim to address:

SRQ1: How do they manage relations in the ecosystem?

SRQ2: How do they identify partners and form value networks?

SRQ3: How do they decide and manage investments?

SRQ4: How do they develop their innovations?

SRQ5: Why do they adopt these approaches?

In attempting to address this combination of questions, a more holistic and potentially systemic perspective on innovation may be elucidated.

Kierkegaard once noted that life is most clearly understood backwards,
but it must be lived forwards.

4 Research Methodology

4.1 Introduction

In this chapter, the research approach is described in terms of the overall design, the philosophical positioning, the type of research questions being addressed together with the methods and analysis employed.

The fundamental nature of this research is to understand *how* organisations innovate in conditions of convergence and in doing so, identify what agency, processes and capabilities are needed. Given the evolving nature of the observed innovation initiatives and the need to explore organizational capabilities and managerial agency at a level of detail and nuance, a qualitative approach was deemed the most appropriate (Meredith, 1998; Yin, 2014).

Understanding innovation in nascent and convergent ecosystems, addresses an established gap in the literature (Enkel and Gassmann, 2010; Forbes and Kirsch, 2011; Harrington et al., 2012). Furthermore approaches to studying such ecosystems, which are nascent, yet complex and dynamic, are not well established (Oh et al., 2016; Ritala and Almpanopoulou, 2017; Rong, 2011), so as part of this research an approach to studying these is developed, which aims to contribute to the methodology literature.

Many previous studies in innovation and new ventures rely on retrospective accounts, long after the events (see for example, Jones & Holt, 2008). However the perspective taken here is that the actions of innovators is largely as a result of 'path creation' and in line with Garud et al. (2010, p. 770), "*it is important for a researcher to study processes in 'real time', i.e. place oneself at the time that events occurred*". So, accordingly the approach taken here diverges from typical retrospective approaches by using contemporaneous accounts and evidence, using a combination of interviews, documents and observation, and by making refinements to the research process as new evidence and phenomena are uncovered. By taking this approach, small details, that maybe impactful, are less likely to get lost in "the passage of time". The approach is designed to address calls by innovation scholars, notably Garud et al (2013) to take a multi-level, longitudinal perspective, and to follow events implicating actors, artefacts, and institutions over time and, in addition to paying attention to the context, to understand the sub-text of agency.

4.2 Philosophical Approach

4.2.1 Philosophical Positioning

The main approaches in terms of research philosophy for business and social sciences are described (Saunders et al., 2012) as:

- **Positivism**, assumes a rational world, which can be measured objectively and thus favours quantitative, and a 'scientific' reductionist approach
- **Realism**, assumes that reality, or some aspect of it, is ontologically independent of our perceptions, but that our beliefs are only an approximation of reality
- **Interpretivism,** or relativism, assumes the 'facts' are socially constructed (constructivism) and subjective (subjectivism), and that the researcher or observer influences the observed phenomena.

A summary of different philosophies and associated research approaches and methodologies are depicted in Figure 4-1 which has been adapted from Saunders et al., (2012). Traditionally operational research and management sciences were rooted in positivism (Meredith 1998), although it is argued that despite the 'positivist' claims many methodologies are either not stated or are actually a mix of methodologies, drawing on different philosophical stances (Mingers, 2003).

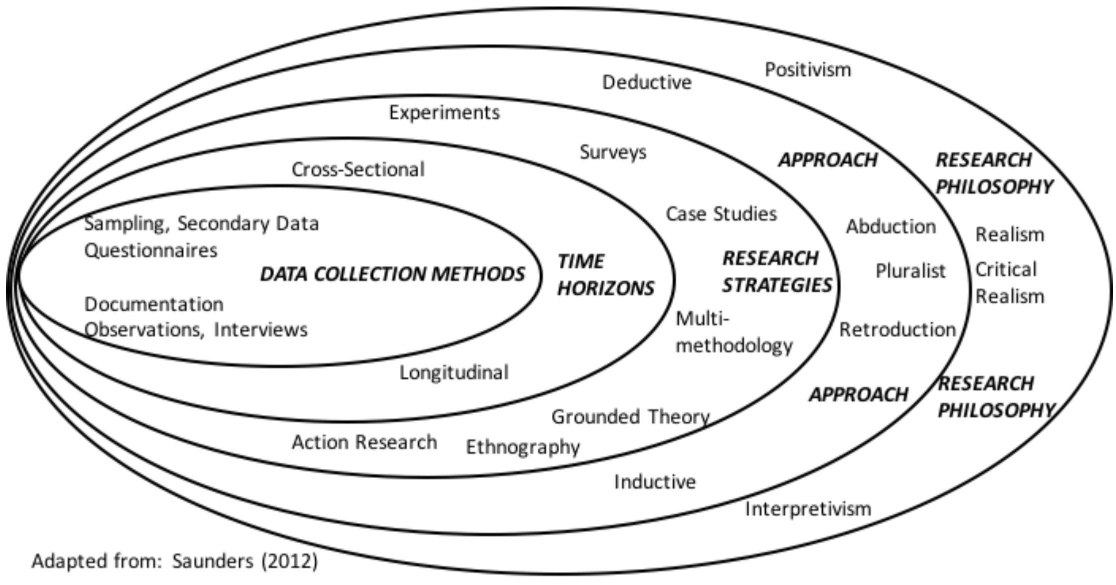

Figure 4-1 Summary of research philosophies and methodologies

The nature of this research is exploratory and investigative, to identify impactful or causal factors, therefore a high degree of interaction with study subjects is anticipated. However, many of the issues and challenges (such as how networks are formed) are not measurable *per se*; this would suggest a qualitative interpretive or realist approach is more appropriate. Boulding

(1987), analysing the epistemology of complex systems, identifies that the methods need to be appropriate to the system and that different methods may be required for different systems, thereby advocating a *multi-methodology*.

4.2.2 Critical Realism

The European perspective on critical realism (CR) in social sciences is traditionally associated with Bhaskar (2011, 2008, 1998, 1989, 1986) who makes an important distinction between *ontology* (what exists) and *epistemology* (knowledge of what exists). At its simplest, critical realism combines a *realist* ontology (the belief that there is a real world that exists independently of our beliefs) and a *constructivist* epistemology (that our knowledge of the world is inevitably our own construction, from a specific vantage point or perspective). Many authors build upon the foundations of Bhaskar, including Archer (1995), Campbell (1988), Cartwright (1999), Tsoukas (1989), Pawson and Tilley (1997), and Miles and Huberman (2014). Thus, a range of methodologies are available to address issues of causation in complex social systems.

Causation and mechanisms

The identification of underlying causal mechanisms (i.e. innovation actions and routines) are a key component of this research. CR has the potential to address this, as: "*the fundamental tenet of critical realism is that we can use causal language to describe the world*" (Easton, 2010). Bhaskar (2008) defines an 'event' as a specific happening or action resulting from the enactment of one or more 'mechanisms'. But whilst mechanisms may be activated, it is also possible that no change occurs because of the counteracting effects of one or more other mechanisms (Tsoukas, 1989). Further, in the context of this research, causation is agential (Howe, 2012) and therefore intentional, determined by a combination of 'objects' (processes or structures) having 'causal powers or liabilities' that are triggered in some 'context or condition' to create an 'event' (Figure 4-2).

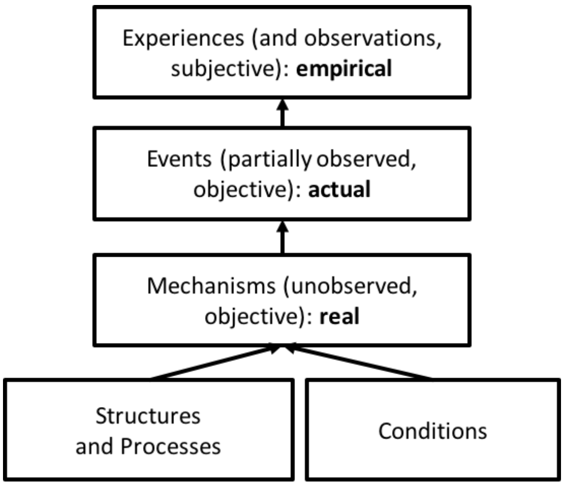

Figure 4-2 Causation as viewed by critical realism

For Bhaskar (2008) causal mechanisms sit primarily within the structural component, in the powers and resources of institutions and organisations. Others, including Pawson (see Pawson, 2013; Pawson and Tilley, 1997), take the view that mechanisms reside within the reasoning of actors and contend that data construction should be theory driven – "*the researchers theory is the subject matter of the interview, and the subject (stakeholder) is there to confirm, to falsify and above all to refine that theory*" (Pawson and Tilley, 1997, p. 155). This however, presumes that theory is already established, which may be problematic in studying nascent systems, with limited prior research. Mechanisms can therefore have different meanings depending on context and intended explanations.

To address this the initial phase of the research specifically considers context, aiming to understand the nascent ecosystem and the implications in terms of conditions or limitations this poses to organisations to either mediate or moderate their actions (Chen, 2005, nn. 240-241). Bhaskar (1989) developed an approach, the 'Transformational Model of Social Activity' (TMSA) to link observations to underlying causal mechanisms, but this is considered problematic to use. Archer's (1995) morphogenic approach, therefore builds on Bhaskar's TMSA through three stages: conditioning, interaction, and elaboration. More importantly, "*the relationship between causal powers or mechanisms and their effects is therefore not fixed, but contingent*" (Sayer, 1992, p. 102); that contingency depends on the context, or local conditions, which in a nascent ecosystem, may change during the research. The approach adopted therefore must address ways in which structures of necessarily related entities cause events to occur (Sayer, 1992) and take account of temporal effects.

Inference

Within qualitative research there are a range of options for inference - the basis for reaching conclusions. A comparison of the four main modes of inference in qualitative research, namely:

deduction, induction, abduction and retroduction, is summarised in Table 4-1, which is derived from Danermark et al. (2002, p. 80). No single approach would appear appropriate to this research. The intent to understand the wider ecosystem, would suggest an inductive approach initially, thereby ensuring the context is expressed as closely as possible in the terms of the actors (Gioia et al., 2012). Then the output may guide the development of later research, which would suggest combining the empirical output and relevant theory (or literature) sources via abduction. For the case research induction, abduction or retroduction may be appropriate, but given the context sensitive and changing nature of events, a retroduction approach would appear the more relevant. Unique to CR, retroduction (Bhaskar, 2008; Easton, 2010) is a 'backwards' process, essentially addressing the question: what must be true to make this event possible? "*Retroduction is a meta-process the outcome of which is the identification of mechanisms that explain what caused particular events to occur. Its adoption does not imply that the mechanisms are postulated then data collected or that they are "induced" from the event data. In practice the process is likely to be an iterative one*" (Easton, 2010, op. 124).

Implications for methodology

Maxwell (2012) and Danermark et al. (2002) identify several CR-based approaches in qualitative research, the fundamental principles of which are used here to guide the development of the case methodology. Pawson and Tilley (1997) developed a widely used approach to link *context to mechanism to outcome* (CMO) and argue that, to improve rigor, observations should be based upon multi-methodology. Bhaskar (2008) building on the concept of retroduction, developed a method known as DREI: <u>d</u>escribe the events of interest; <u>r</u>etroduce explanatory mechanisms; <u>e</u>liminate false hypotheses; <u>i</u>dentify the correct mechanisms. This approach aims to explain events by identifying and verifying the existence of mechanisms which are theorised to have produced them. Others including Archer (1995) and Easton (2010) have built upon this approach, providing practical methodologies. Sayer (1992) also developed Bhaskar's original 'DREI' approach, providing a clearer means for inference. A modified version of this is proposed (Figure 4-3), which recognises that the context and conditions may be independent of the objects and causal powers.

Table 4-1 Modes of inference in qualitative research

	Deduction	**Induction**	**Abduction**	**Retroduction (CR)**
Fundamental Structure and thought operations	To ***derive logically valid conclusions*** from given premises. To derive knowledge of individual phenomena from universal laws	From *several observations to draw universally valid conclusions* about the whole population. To see similarities in a number of observations	To interpret and recontextualize individual phenomena within a conceptual framework. ***To understand something by observing and interpreting in a new conceptual framework****.*	From a description and analysis of phenomena to ***reconstruct the basic conditions for these phenomena to be what they are.*** Using thought operations and counterfactual thinking to argue towards transfactual conditions
Central Issue(s)	***What are the logical conclusions of the premises?***	***What is the common element for a number of observed entitles? Is it true of the wider population?***	***What meaning is given to something interpreted within a particular framework?***	***What must exist for something to be possible?***
Strength	Provides rules and guidance, logically valid	Provides guidance	Provides guidance for interpretative processes to enable meaning to be ascribed	Provides knowledge of transfactual conditions, structures and mechanisms that cannot be directly observed
Limitations	Deduction does not say anything new about reality, beyond existing premises. It is strictly analytical.	Inductive inference can never be either analytically or empirically certain. Restricted to conclusions at the empirical level	There are no fixed criteria to assess the validity of an abductive conclusion	There are no fixed criteria to assess the validity of a retroductive conclusion
Required research approach	Logical reasoning ability	Statistical analysis Pattern analysis	Creativity and imagination	Ability to abstract

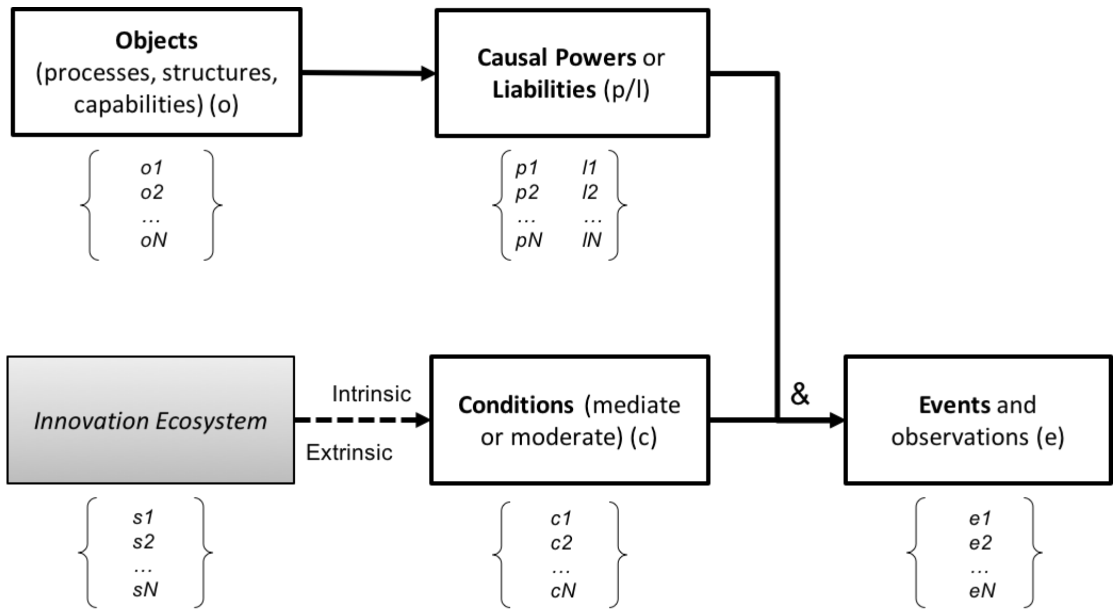

Figure 4-3 Causation mechanism developed for this research

In a further development, Danermark et al. combined Bhaskar's, Easton's and other CR approaches into their six step Explanatory Model (Danermark et al., 2002), although this has not been widely used (Raduescu and Vessey, 2008) it, along with the Easton method, offer some avenues for method development for this research. Taking the six-step process as a starting point and combining with the causation mechanism, the application of this approach to this research is summarised in Table 4-2.

For this research a combination of induction, abduction and retroduction would therefore appear to be most relevant. However, unlike other forms of research, in CR the analysis is not carried out in the last phase of the research, but data gathering and analysis take place in parallel – so there is a need for reflection as the research proceeds (Easton, 2010; Sayer, 1992), including cross-case analyses. In essence, there is a need to '*make sense of the interpretations of others*', by segmenting data, categorising, and comparing. So, for example, using comparative methods in coding to find similarities and then refine categories (coding) that grow out of the data (Saldaña, 2013).

From a CR perspective, an explanation of a causal mechanism requires a theoretically guided analysis of the relationships between generative processes (by which entities with causal powers or liabilities, cause events), conditions (which may mediate or moderate causal tendencies) and outcomes (the observable events) (Ackroyd, 2009; Edwards et al., 2014; Sayer, 1992). Since causal factors may not operate in the same way for all cases, this study seeks to explain the relationship between the phenomena of interest by factoring in the combination of conditions found in each case.

Table 4-2 Six step method of Danermark and its application

CR Method - Danermark et al (2002)	Interpretation and Application to this Research
Description of phenomena: *Context, activities and events*	Description of phenomena: *Healthcare, convergence and innovation activities* *Ecosystem 'building'*
Resolution (and focus): *Identify components to be studied*	Resolution (and focus): *'Convergent' Innovation processes and Capabilities*
Abduction (theoretical description): *As an exploratory framework based on literature and empirical evidence*	Abduction (theoretical description): *Develop an Exploratory Framework for 'convergent innovation' using preliminary ecosystem findings*
Retroduction (causal mechanisms): *From events, context/conditions, causal tendencies/liabilities, to generative mechanisms and structures*	Retroduction (causal mechanisms); *Conceptualized processes that might underpin observed activities in cases and resolve to a model*
Comparison with alternative theories / abstractions: *Assess relative explanatory power vs alternatives (i.e, elimination in Bhaskar)*	Comparison with alternative theories / abstractions: *Assess relative explanatory power of the proposed model vs alternatives*
Concretization and contextualization: *How structures and mechanisms manifest in concrete situations (via Cases)*	Concretization and contextualization: *Evidence from case events/observations with conditions/context, and tendencies/liabilities, to define objects (processes and capabilities) to provide direct 'evidence' to support explanations*

With a small number of cases, even with case diversity, there are likely to be limited number of generative mechanisms. This study is, thus, characterised as *intensive multiple case studies* (Ackroyd, 2009; Ackroyd and Fleetwood, 2000) allowing the understanding of interacting causal mechanisms in various contexts (see Figure 4-4). However, sampling is strategic, and not statistically representative (Sayer, 1992).

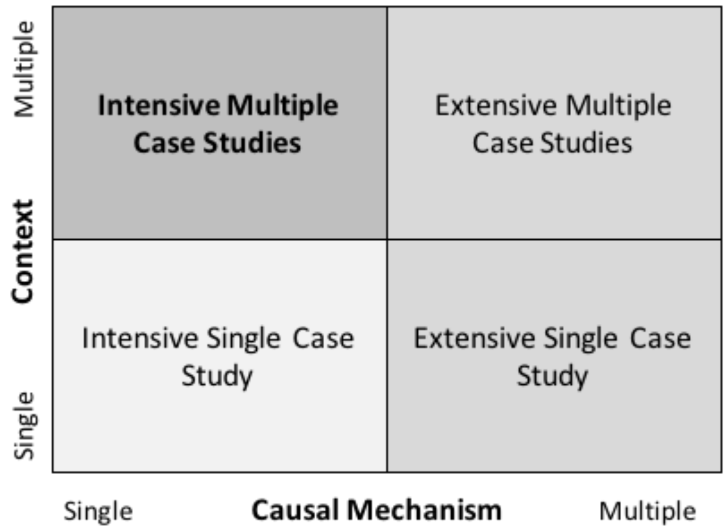

Figure 4-4 Case study typology in critical realism (from Ackroyd and Fleetwood, 2000)

Verification and falsification

As mechanisms in complex systems that result in an identified action or event cannot be directly observed a key requirement to improve methodological rigor is the ability to verify or falsify alternative explanations. This presents problems where direct observation is not possible, as classic techniques like triangulation (Yin, 2014) are not viable. Instead Sayer (1992) and Collier (1994) provide CR–consistent approaches to help verify or show falsification of causal mechanisms, by considering multiple plausible explanations and seeking to eliminate the *least* plausible. Multiple sources provide one such avenue, for example conducting interviews with multiple knowledgeable but diverse sources, combining interviews with other data sources (Dubois and Gadde, 2002). In terms of this research, using multiple interviewees, multiple sources and multiple cases provides an opportunity to seek corroboration to support explanations (Easton, 2000).

Conclusions

To conclude, as seen from critical realist perspective this research would be considered as: *an intensive, passive multi-case study to identify context-mechanism interactions*. However, recognising the research is taking place in the context of complex system, a nascent and emerging innovation ecosystem, there is also a need to address ecosystem study more robustly, to provide good context and 'condition' evidence (from Figure 5.3.5) for the determination of causal mechanisms. Research recommendations by both

Midgley and Mingers would suggest a pluralist approach, mixing methodologies to enable alternative perspectives to inform the research (Midgley, 2008, 2003a; Mingers, 2006). This would imply employing critical realism but recognising the need for systems thinking to understand the context, and thus using mixed methodologies.

4.3 Overall Research Approach

Having identified an overall philosophy and its implications for the methodology, the actual research approach is now considered. As previously identified one challenge in this research is that the innovations and the cases are taking place within a nascent and highly dynamic ecosystem. Whilst aiming to understand how organisations innovate, the 'diffusion of (their) innovation' (Rogers, 2003), requires that the innovation must meet a customers perceived need, or needs, and also be compatible with their other important beliefs and practices (Maxwell, 2012). Thus, taking a more holistic or systemic view (Midgley, 2003b) of innovation would appear to be an important step in understanding how organisations innovate in these complex ecosystems.

Therefore, to provide context and the 'conditions' to assess causal mechanisms, the first step (phase 1) is to understand the wider innovation ecosystem and then those specific to each case. Initially, to accurately capture the input of individual actors' perspectives on the ecosystem, an inductive approach is suggested. The output of phase 1 together with a review of the relevant literature, using abduction, is used to build an exploratory framework for phase 2.

Having addressed the context, next a series of longitudinal in-depth case studies (phase 2) each investigating a firm and its evolving innovation are used to identify processes and routines for innovating in nascent ecosystems. Adopting such an approach infers different modes of inference, at different phases. The inference for the case research uses retroduction to elucidate plausible mechanisms and models. The overall research approach is depicted in Figure 4-5.

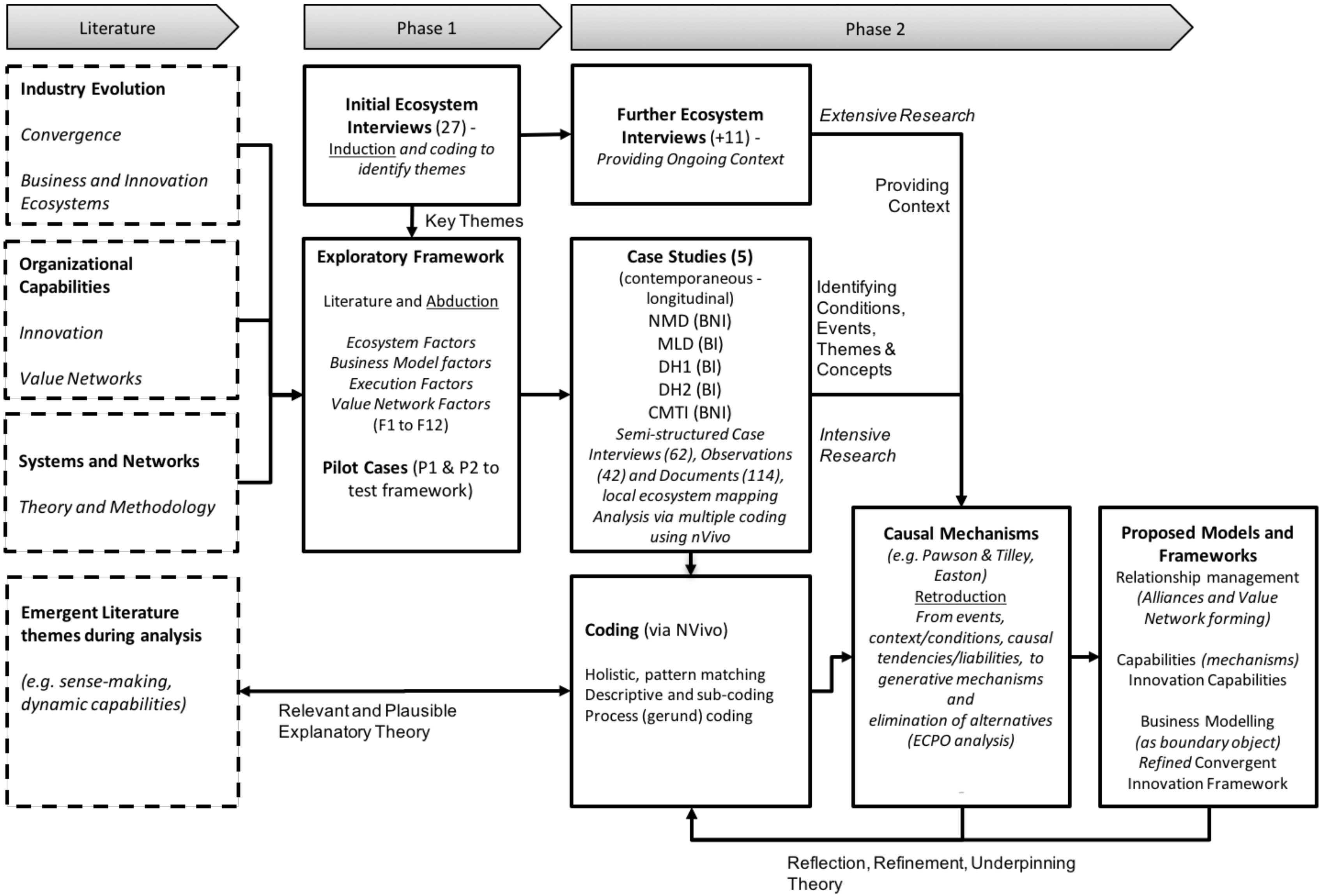

Figure 4-5 Overall research scheme

4.4 Studying Ecosystems – development of an approach

As previously identified in section 2.3, there are challenges in studying business and innovation ecosystems. From a methodological perspective, business ecosystems present an interesting challenge as research approaches have varied from an exploration of a key actor's role (Ritala et al., 2013), inter-firm relationships and networks (Basole et al., 2015), industry analysis (Ansari et al., 2016) or more holistic ecosystem phenomena. However, much of the research appears to use 'ecosystem' primarily as an analogy or inspiration given the methodological challenges (see also Oh et al., 2016). As identified earlier, what is lacking is a 'meta-level' methodological approach to systems-based forms of organizing which would address the perceived shortcomings of various, narrower approaches and match the theoretically ambitious aims of ecosystem scholars, such as co-evolution (Adner and Kapoor, 2010) or collective institutional logic formation (Vargo et al., 2015). The challenge in the current literature lies in the multitude of different studies with different foci, which is especially visible in the recent ecosystems literature (see e.g., Oh et al., 2016). This diversity of approaches makes synthesis and cross-study inferences more problematic, which in turn inhibits the development of a solid theoretical and methodological base, and potentially slows down the progression of scholarly knowledge on this important topic. This is an important research gap (Oh et al., 2016; Ritala and Almpanopoulou, 2017).

To address this, it is proposed to develop a complex adaptive systems research approach and related methodological framework to provide a better means to examine these systems-based phenomena. Developed from the ideas of Cabrera (2008), the approach envisages three specific dimensions in this regard, namely; *conceptual, physical* and *temporal*. These dimensions have been addressed within systems sciences and related fields (Anderson, 1999; Cilliers, 2001; Holland, 1995; von Bertalanffy, 1968), but they are not explicitly or exhaustively addressed in the research approaches in studying ecosystems.

The key elements of the research framework have been developed by taking a systemic approach to understanding ecosystems (Phillips, 2015). This has been further developed to "PBSRDC" (perspectives, boundaries, structure, relationships, dynamics and co-evolution), summarised in Table 4-3 with the example activities for each of the conceptual, physical and temporal dimensions are depicted in Figure 4-6, Figure 4-7 and Figure 4-8.

Table 4-3 Conceptual, physical and temporal dimensions and their implications

	Conceptual	**Physical**	**Temporal**
	How we think about the system..?	***What we know about the system..?***	***How systems change over time..?***
Systems-theoretic definition	The epistemology and theoretical considerations and their implications for the ecosystem research scope and design.	The ecosystem components and the relationships between them that impact 'structure' and processes.	The temporal considerations impacting the dynamics and evolution of the ecosystem.
Key focus of systems-based inquiry	**Perspectives**: how to address the differing perspectives of actors, the ecosystem, and its environment **Boundaries:** determining the type and scope of ecosystem being considered (e.g. business, knowledge, innovation)	**Structure:** the components (actors) in the ecosystem study, which may include sub-systems and individuals **Relationships:** the links (and their nature) between components (actors), driven by actors processes (schema)	**Dynamics:** the changes in the ecosystem, actors, relationships and boundaries over time **Co-evolution**: the interdependent evolution within the ecosystem *and* with its environment
Key research design questions	*What is the focal issue?* *What philosophical and theoretical positioning is appropriate?* *What are the implications for the scope and determining the boundary?*	*What structures, processes and relationships should be considered?* *How might these be mapped and studied?* *What is/are level(s) of analysis?*	*What are the underpinning dynamics (of the environment, ecosystem and its components)?* *What time frame and approach is appropriate?* *How might time impact the conceptual and physical considerations?*

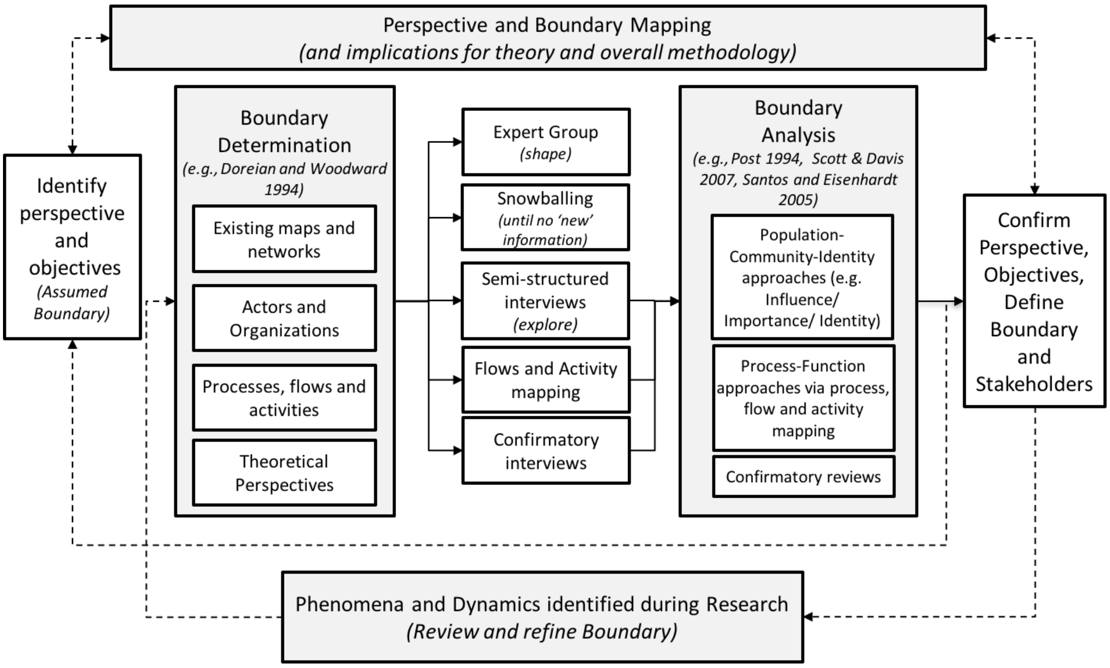

Figure 4-6 Methodological framework to identify boundaries, perspectives and objectives

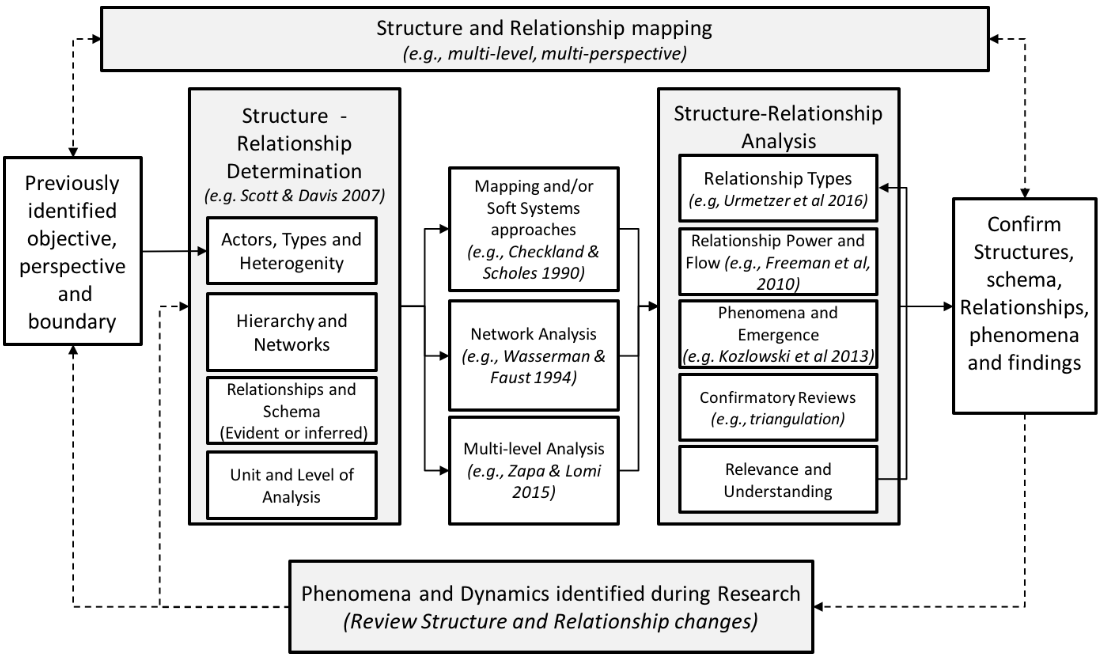

Figure 4-7 Methodological framework to address system structure and relationships

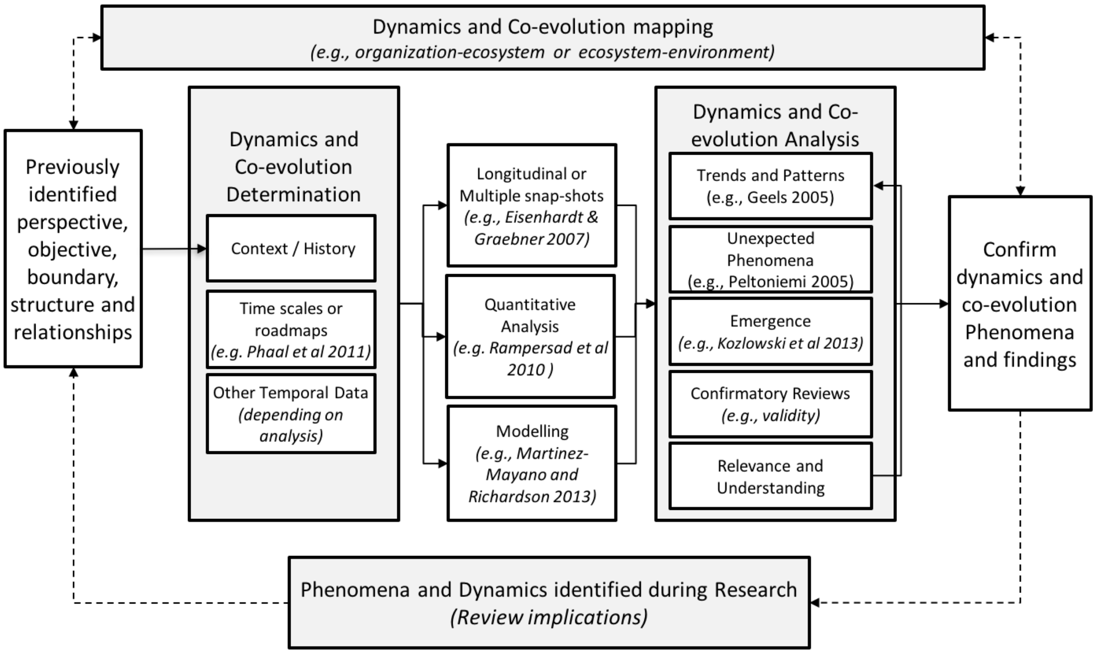

Figure 4-8 Methodological framework to address system dynamics and co-evolution

Developing this approach was considered a necessary precursor for undertaking the key research objective, as such it is a further objective of this research, but not its focus. Consequently, in the interests of brevity, there is limited discussion on the development of the approach here, but the early development is summarised in Phillips (2015). This approach contributes to the field of organizational research by moving forward from using "ecosystems" as an analogy, towards studying ecosystems as a systems-consistent methodological approach, thus addressing identified gaps (Oh et al., 2016; Ritala and Almpanopoulou, 2017) in the ecosystem literature.

4.5 Data Collection and Analysis

In this section, the general approach to data collection and analysis will be discussed. Discussion on specific methods employed during the case studies will be covered in later sections. All data collected was stored on a secure, password-protected cloud-based server. Data was imported into a CADQAS software package (NVivo 10 and later NVivo 11)[1] to enable coding and analysis. Much of the data collected remains subject to non-disclosure and confidentiality agreements as the data pertains to ongoing innovation projects. However, data and key analysis is presented in an anonymised form in this thesis.

[1] NVivo is a trademark of QSR International Pty Ltd, Australia

4.5.1 Units and Levels of Analysis

As identified earlier, units and levels of analysis present challenges in studying ecosystems, as multiple units and levels exist. To understand causality an investigation of each may be required. The first part of this research, to understand the emergent healthcare technologies ecosystem requires a 'system view', with the unit of analysis as the wider health care *innovation ecosystem* itself. For the subsequent case research, the unit of analysis moves to the firm specific innovation ecosystem and specifically the innovation project or venture undertaken.

The second phase of the research considers the routines and actions required to create and deliver innovation. This could be undertaken at a focal firm level, although where multiple organisations are involved this may be limiting. There are also arguments for using multiple 'units of analysis' (Mingers and Brocklesby, 1997), but given the nature of convergence it makes more sense to explore each innovation case from the perspective of each venture or innovation. This would include the *orchestrator* or *lead firm and other key collaborators and their stakeholders* in the research case. By considering the different stakeholders, different perspectives on how that project or product is valued and the capabilities needed by different value network partners can be assessed.

In addition to the innovator cases, an on-going study of the wider ecosystem, through further interviews was continued (extending the earlier preliminary research), thus enabling an up to date context to be provided. The on-going study of the ecosystem, as with the preliminary research phase, used the ecosystem itself as the unit of analysis.

So, in essence this research is multi-level (Klein and Kozlowski, 2000; Kozlowski et al., 2013; S. W. J. Kozlowski and Klein, 2000), considering the wider ecosystem, the immediate innovation ecosystem and key firms' ventures. Levels of analysis have typically received less attention in the research literature (Tight, 2012), but are key in complex systems, where emergence, and lower level dynamics, result in phenomena elsewhere in ecosystem.

4.5.2 Interview Data

Preliminary Ecosystem Interviews

The initial phase of the research started by identifying an 'expert group', with knowledge of the field, and using them to identify initial interviewees. Starting from these interviewees snowballing (Goodman, 1961) was used to access other actors and knowledge. The research process at this stage was essentially inductive, the objective being to identify what stakeholders believed were the key issues and what constituted the ecosystem boundary. The approach used semi-structured interviews with senior leaders in innovator companies, venture funds, customers, regulators and academics (see Appendix A1 for ecosystem interview protocol). Where possible interviews were recorded, but in many instances this was not possible, so contemporaneous notes were always made and these were written up promptly and coded. Along with the interview notes, a 'map' of the ecosystem actors identified during the interview was also made.

Interviews were coded and at first this was achieved using Excel spreadsheets, but later CADQAS software (QSR's NVivo) was used to improve methodological trustworthiness (Healy and Perry, 2000) and coding efficiency (Bazeley and Jackson, 2013; QSR International, 2014). The key issues and identified ecosystem actors were tracked as interviews progressed. After around 20 interviews it was evident that little 'new' information was emerging from these interviews. So, it was decided to complete this phase, however three more preliminary interviews were completed as the interviews had already been scheduled, giving in total 23 preliminary interviews. These additional interviews, as expected, revealed little new information, thus increasing confidence that the key issues had been identified.

Confirmatory Ecosystem Interviews

Following the initial analyses to identify the key 'dimensions' and development of an initial ecosystem 'map', four further interviews were conducted, again using senior leaders, but selected to be from diverse parts of the mapped ecosystem. These interviews were used to confirm or verify initial findings in terms of ecosystem actors and boundaries and the key issues, thus supporting construct validity (Gibbert et al., 2008).

The analysis in Phase 1 followed the methodology of Gioia et al. (2012), which is discussed in more detail in Section 4.5.6. These *verified* 'dimensions' then formed the starting process for abduction, which together with relevant literature were used to refine the 'dimensions' to develop an Exploratory Framework (the analysis and development of this is discussed in Section 5.1).

Case Interviews

The Exploratory Framework was used as an interview guide, but was not prescriptive. Instead it identified broad themes and areas to explore as part of the case study. Case interviews were also semi-structured, enabling interviewees to explain, in depth, from their own perspective (Gioia et al., 2012). For each case the interviewees were key managers in the innovator firm, or senior leaders in their alliance partners, as such, the interviewees were considered to be knowledgeable and credible sources.

4.5.3 Interview conduct and processes

Interview protocols were used for the preliminary, confirmatory and case interviews; these are included in Appendices A1 and A2. Where permitted, interviews were recorded. Contemporaneous interview notes were made at every interview. But as all the case studies involved confidential projects which are still ongoing (at time of writing), all were subject to non-disclosure agreements and so, reporting is anonymous. The interview methodology used follows Halcomb (2006), with minor modifications to account for there being only one researcher being involved. This process is summarised in Table 4-4 and was used for the preliminary and case interviews.

To build confidence in the interview process initial experiments used field notes alone (knowing that some interviews could not be recorded) and then used notes with an audio recording and a full transcription. Finding that full transcriptions offered limited additional information to that captured in the notes, other than useful verbatim quotes, transcriptions were used to check key points. So, note taking was refined to identify key issues, that could then be verified by listening to the recording or identify quotes to transcribe. As this research was not an in-depth ethnographic study aiming to identify subtle nuances, but is more about identifying key actions and the underlying mechanisms, this approach was considered acceptable.

Details of the interviews, including information on interviewees are provided in the relevant sections on the preliminary research, ecosystem study, and each case report and in Appendix A4.

4.5.4 Observations

During the case studies, direct observation was also undertaken (e.g. at workshops, planning meetings or project reviews). Evidence was captured in the form of field notes and photographs (e.g., of workshop outputs or events) and where permitted in the official meeting minutes. This provided an opportunity to obtain contemporaneous and unfiltered evidence to supplement that obtained from interviews. However, it is noted that there are limitations, as identified by Dosi (1997), as agents have an imperfect understanding of the environment, and even more so of what the future will deliver, hence '*bounded rationality*' was assumed and attempts were made to corroborate any observation with further interview or documentary evidence. Details of the observations are provided in the relevant sections on the ecosystem study and for each case.

Table 4-4 Interview Process (based on Halcomb, 2006)

Step	Process Description	Method Comments
1	Explain interview objectives Take field notes, i.e. record observations and interviewees explanations Make audio recordings (where permitted)	Explain Background to research and interviewee background for context Extensive handwritten notes taken during interview, with key sections for audio checking highlighted.
2	Write up journal notes. Immediate reflection on issues identified.	Notes were written up within 24 hours and then reflected upon for key issues, highlighting these for subsequent coding.
3	Use audio playback to check notes and refine interview records, especially for key issues. Transcribe key quotes from audio into notes.	Used audio recordings where permitted Used recording to check key issues and obtain verbatim quotes. Notes typed up in MS Word, then added to CADQAS database for logging and coding.
4	Conduct primary context analysis and coding (1st coding)	Identified areas to follow up in subsequent interviews
5	Further thematic coding and analysis	A range of different coding and analysis approaches were used depending on whether they were ecosystem level or individual case interviews

4.5.5 Documentation

A further source of data, for the wider ecosystem and each case study was documentation. This included both company confidential information, obtained under non-disclosure agreements, such as project proposals, board papers, project reviews, and internal reports. Use was also made of public documents via news reports, press releases or websites as supplementary evidence. The main use of this documentation was to help corroborate interview and other evidence. Details of the key company and public documents used are provided in the relevant sections on the ecosystem and each case.

4.5.6 Data Coding and Analysis

Preliminary Ecosystem interview coding

The interviews were analysed using a process based upon the Gioia (2012) method. First order coding was generally holistic and *in vivo*, using the sources own words and short phrases to guide coding (Saldana, 2013, p. 91 and 142), thus avoiding early influence or bias in the analysis. Second order coding largely followed a pattern matching approach (Saldaña, 2013, p. 209) to identify emerging themes. The final stage was to use axial and focussed coding (Saldaña, 2013, p. 213) to aggregate these into 'dimensions' that summarised the key issues within the ecosystem. An illustration of the process used for these coding cycles, reproduced from Gioia et al. (2012, p. 21) is provided in Figure 4-9.

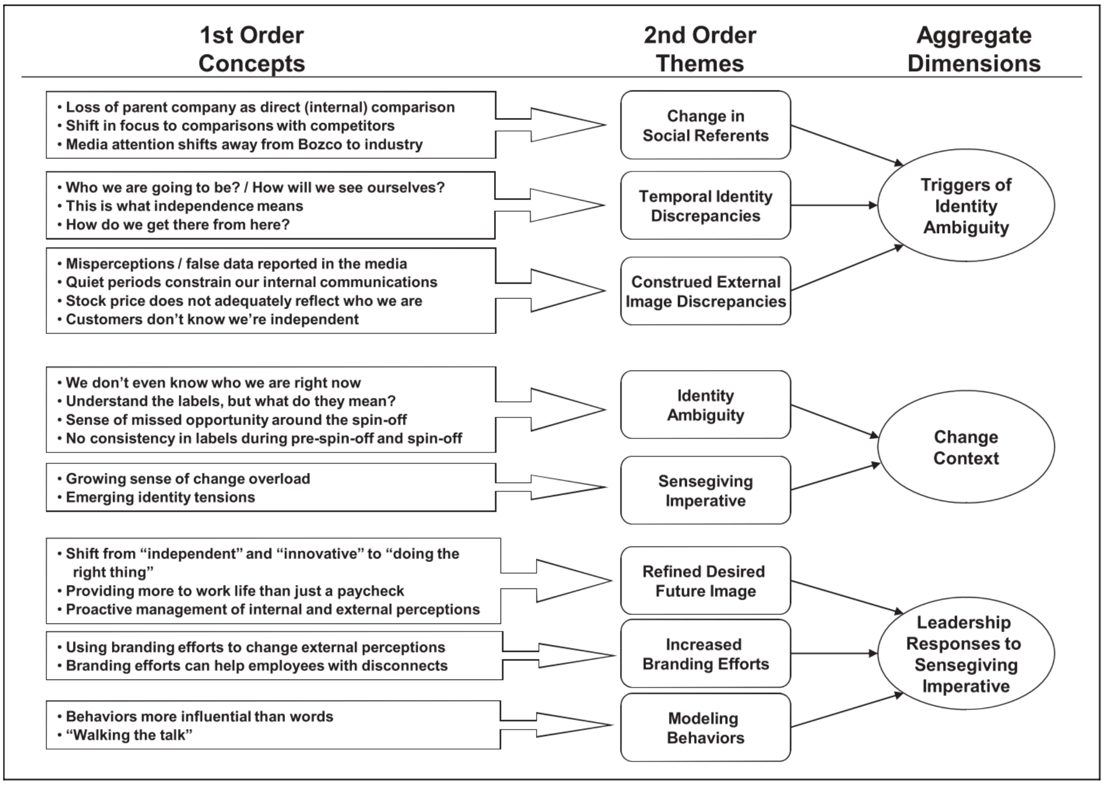

Figure 4-9 Illustration of preliminary research analysis (reproduced from Gioia et al., 2012)

Coding and Analysis were completed for all 23 preliminary ecosystem interviews, resulting in over 800 coding references. The aggregate number of coding references for each coding node and the number of interviews where that code was identified are summarised in Table 4-5. The 'challenges' and 'opportunities' are in direct response to interview questions; the other themes arose from *in vivo* coding. As the ecosystem was nascent, and complex, adopting this approach provided an initial 'holistic' view to identify and understand key issues from the perspectives of the stakeholders or actors, before refining the research focus.

The output of this analysis was used as the basis for the development of the Exploratory Framework (see Chapter 5 for details), which was then used to inform and guide Case Study research.

Case Study data coding

Following the development of the Exploratory Framework described in section 6, case coding followed approaches recommended by Saldaña (2013) and by Miles and Huberman (2014). Case coding involved coding of interviews, observational data and documentation and is discussed in more detail in section 0. Coding was conducted during the research, to enable ongoing reflection, consistent with realist approaches (Easton, 2010; Sayer, 1992). It was designed to address determination of causality (as shown in Figure 4-3) and is discussed in more detail in the case study section.

Table 4-5 Summary coding of initial ecosystem interviews

Initial Coding Nodes (aggregate level)	Aggregate number of coding references	Aggregate number of interviews where coded
Business Model and value creation	97	18
Challenges	128	23
Customers - Stakeholders	138	22
Ecosystem understanding	122	21
Funding and investment	50	18
Innovation Processes and capabilities	201	23
Opportunities	61	20
Regulation-Policy	21	9
Value Network	81	20

4.6 Case Study Methodology

The following section discusses case selection (including criteria), case methodology, data collection and coding, and case data analysis.

4.6.1 Case Selection Criteria

Miles and Huberman (2002; 2014) recommend using selective sampling to improve research efficiency. As the research seeks to identify how convergent innovations are developed, the case studies draw from *across* the wider ecosystem and from different domains of 'convergence', to get perspectives of different types of '*producers*', with different 'customers' and 'stakeholders'. To supplement these studies and to provide an alternative perspective, an 'incubator' as a Case Study was included. This case developed their strategy to support convergence and an 'ecosystem' of small entrepreneurial firms, which may provide additional case study options and different perspectives on 'value', 'capabilities' and institutional gaps.

Several criteria were identified to help select cases. As the research was exploring innovation in the context of convergent or cross-industry innovation (Enkel and Gassmann, 2010; Rikkiev and Mäkinen, 2013; Stieglitz, 2003), cases needs to be drawn that were clearly crossing traditional domains. The domains of interest in this research are biomedical sciences (B), novel materials and nano sciences (N) and information or digital science's (I), as described by Bernabo et al. (Bernabo et al., 2009a) and Shmulewitz et al. (2006). An object was to obtain cases that spanned these domains (e.g. BNI, BN and BI), see Figure 4-10. Additional criteria were to consider organisational variety with small or start-up organisations, and in large or multi-national companies and also the type of innovation with diversity in product/service (Hacklin and Wallin, 2013) or platform or infrastructure (Gawer and Cusumano, 2013; Walsh and Linton, 2000). Given that the intention was to study innovation practices contemporaneously, a conclusion, such as a successful launch, might not be observed, so surrogate indicators of 'success' were required, such as the study period including an important inflection point or transition (e.g., major investment, new organisation formed, regulatory submission). The final consideration was theoretical sampling (Eisenhardt and Graebner, 2007), and access to the value network, alliance partners and stakeholders, and data. No clear guidance for the number of interviews and interviewees that might be acceptable was identified in the literature, for a realist and in-depth study it has been argued that the sample size can be small (Crouch and McKenzie, 2006). Crouch and McKenzie further suggest: "*The work of linking interview account– continually analysed – and conceptual frameworks – under construction throughout the research – clearly requires small sample sizes so that all the emerging material can be kept in the researcher's mind as a totality under investigation at all stages of the research*" (2006, p. 495). As a result, criteria of at least 10 interviews and access to at least 5 different actors was used as a guide. These criteria are summarised in Table 4-6.

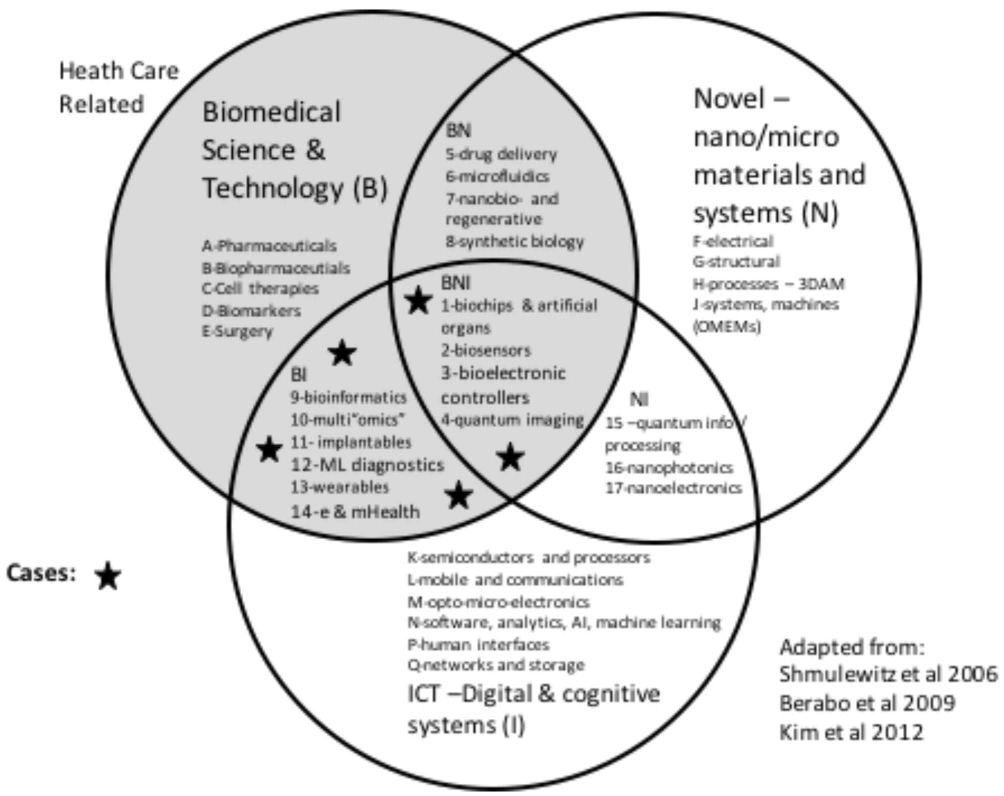

Figure 4-10 Distribution of case studies in BNI convergence domains

Table 4-6 Case selection criteria

Case Criteria	Rationale for criterion
Conducting convergent innovation	Core to the research question
Spans BNI, BN or BI domains (see Figure 4-10)	Cases are diverse and cover a range of domains
Mix of Large (or MNC) and Small (or start-up) firms	To obtain diversity in case firms (and initial capabilities) and help assess whether convergent innovation practices vary in different types of organisation
Type of innovation – product/service, platform or infrastructure	To obtain diversity in innovation type and help assess whether innovation practices vary in different types of innovation
Major Inflection point likely to occur during research period	Used as surrogate for 'success', a major investment or organisation formation is an indicator of internal commitment and continued progress
Access to data and key individuals for a longitudinal study	Access for at least 12-18 months necessary to obtain research data and to observe patterns and dynamics, (preferably the ability to conduct at least 10 interviews and with 5 different actors)

4.6.2 Selected Case Studies

Case identification used a combination of knowledge and contacts from the preliminary interviews, and contacts made at subsequent ecosystem events. In total, thirteen different organisations were approached. For several reasons, such as confidentiality concerns or access to key individuals, many cases were rejected or did not progress. However, five cases that appeared to meet the criteria were identified, these are summarised in Table 4-7.

An original intent was to complete ecosystem interviews before starting case studies, but during the research the process was refined. These interviews were continued (beyond the initial 27) as it became evident that the evolving wider ecosystem may meditate or mitigate potential case actions, so a mechanism to capture system wide data and cross-analyse or triangulate with individual case studies was potentially useful. Thus, the wider ecosystem was effectively considered as a case too, and further interviews, beyond the 'preliminary research' phase were continued.

Table 4-7 Case studies selected

	"Case 0" - Ecosystem	Case 1	Case 2	Case 3	Case 4	Case 5
Case ID	*ECO*	**CMTI**	**NMD**	**DH1**	**MLD**	**DH2**
Unit of Analysis	*Overall Ecosystem*	Incubator Ecosystem	Firm Innovation Ecosystem	Firm Innovation Ecosystem	Firm Innovation Ecosystem	Firm Innovation Ecosystem
Convergence Domain (B / N / I)	*BNI*	BNI	BNI	BI	BI	BI
Diversity in Scale?: *Large organisation: LC, or small organisation: SME and start-up (SU) versus incumbent (IN)*	*n/a*	SME (IN)	LC (IN)	LC (IN)	SME (SU)	SME (SU)
Diversity in Innovation?: *Product (P) or Platform (T) or Infrastructure (I)*	*n/a*	I	P/T	P	P/T	P
Likely 'inflection points' during research period?	*n/a*	Y	Y	Y	Y	Y
Access to data, actors and stakeholders? – *(ideally at least 10 interviews across 5 different actors)*	*Y*	Y	Y	Y	Y	Y (but case terminated early)

4.6.3 Case Method Overview

To understand firms' activities and motivations in-depth research is required. Case studies can accommodate a rich variety of data sources, including interviews, archival data, survey data, ethnographies, and observations (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; Yin, 2014). Each case itself can be considered a 'bounded system' (Simons, 2009, p. 29), a meaningful but complex configuration of events and structures (Byrne and Ragin, 2009). It is argued that the use of multiple case studies can provide a stronger basis for theory building (Eisenhardt, 1989; Yin, 2014, 2003), however this presupposes that causal mechanisms are identified and that any cross case comparison is not superficial (Easton, 2000).

This research is essentially about understanding processes, routines and capabilities. A recognised method for process focussed case based research, is to use longitudinal studies of intra organizational phenomena (Helfat et al., 2007, p. 36), therefore this research is based upon longitudinal case studies (Blazejewski, 2011). However, the key reference on case study research, Yin (2014) makes only passing reference (on pages 51 and 53) to longitudinal studies. Furthermore, longitudinal studies are not really not addressed in any depth by other prominent case authors such as Eisenhardt (for example, see Eisenhardt, 1989; Eisenhardt and Graebner, 2007). Yet, case studies need to be dynamic and be concerned with time if they are to be explanatory in both Yin's (1994, 2014) and in the realist sense; there is a need to uncover temporal patterns (Blazejewski, 2011), particularly in innovation (Garud et al., 2013).

Given the emergent nature of the innovation ecosystems and ventures, sources such documentation and archival records would be limited. Interviews and observations provide the most obvious sources, but have potential drawbacks. Direct observations are time consuming and, interviews risk bias (due to poorly worded questioning, response bias or *reflexivity*) and inaccuracies due to poor recall or records. The aim therefore is to collect data as contemporaneously as practicable to avoid the risks of interviewing that result from the impact of time and other influences (Alvesson, 2003). However, in the case of convergence, the approach also needs to extend beyond the firm to consider wider ecosystem perspectives. The case study methodology largely used recognised approaches as recommended by Yin (1994, 2014), and Eisenhardt (1989), but recognising the complex context and consistent with a systems and critical realist approach, some variations are required. Taking critical realists approach to Case Studies (Easton, 2010; Morais, 2011; Sayer, 1992) involves developing mechanism-centred theorizing to seek causal mechanisms. The implications of taking a critical realist approach to case studies is summarized in Table 4-8 below, with is adapted from Welch et al (2011, p. 745). An implication of this is that the findings from the cases studies are contingent (on context) and have limited generalizability.

The Exploratory Framework formed the basis for the case studies and case interviews. But additionally, each case ecosystem was mapped several times during the longitudinal studies and stakeholder analysis was undertaken to better understand relationships within the ecosystem. A simple timeline was also constructed to describe the dynamics. The previously developed PBSRDC systems framework was used to establish an understanding of context for each case, this context then formed an input to the causal mechanism approach developed early.

Table 4-8 Implications of CR approach to case studies (adapted from Welch, 2011)

Philosophical orientation	Positivist	Relativist	Realist	Critical Realist
Key Proponent(s)	Eisenhardt	Yin	Pawson & Tilley	Bhaskar & Sayer
Basis	Empiricist	Falsification	Plausibility	Plausibility
Exemplified by:	*"Truth is absolute"*	*"Truth is relative"*	*"Truth exists but …"*	*"Truth exists but…"*
Nature of research	Objective approach to generalisation	Objective approach to identifying causation	Subjective approach to identifying causation	Mixed methods approach to identifying causation
Research Approach	Inductive	Internal validity	Identify context-mechanism-outcome (CMO)	Mixes induction and deduction, and retroduction via DREI methods
Nature of causality	Proposes associations between events	Specifies cause-effect relationships	Identifies context-mechanism-outcome CMO causality	Identifies causality via 'object, causal tendencies / liabilities, context and outcomes'
Case outcome	Explanation as testable propositions		Explanation in the form of causal mechanisms	Explanation in the form of causal mechanisms
Applicability to complex systems	Limited by positivist intent, and desire to define cause-effect	Limited by positivist intent, and desire to define specific cause-effect	Partially aligned, but requires each CMO to be embedded in layers	Aligned via multi-methodological and agnostic approach
Generalisation	Generalisable to populations	Generalisation to theory	Contingent and limited generalisation	Contingent and limited generalisation

4.6.4 Case Study Protocol

Case studies were conducted using a case study protocol, which is included in Appendix A2. The protocol was developed from a combination of the PBSRDC ecosystem research approach and the Exploratory Framework.

4.6.5 Case Evidence

The aim in each case was to use the Exploratory Framework to provide the basis for a broad exploration of innovation processes and approaches used. As well as semi-structured interviews, evidence was gathered in the form of observation (of meetings and events) and relevant documents which were either publically available or obtained under a confidentiality agreement with each organisation. An overview of all the case evidence collected is summarised in Table 4-9. Case evidence was collected on a dedicated and secure case-study database (using Dropbox and uploaded to the NVivo database) to heighten reliability (Yin, 2014). An example of the folder structure for case data collection and tools is shown in Figure 4-11.

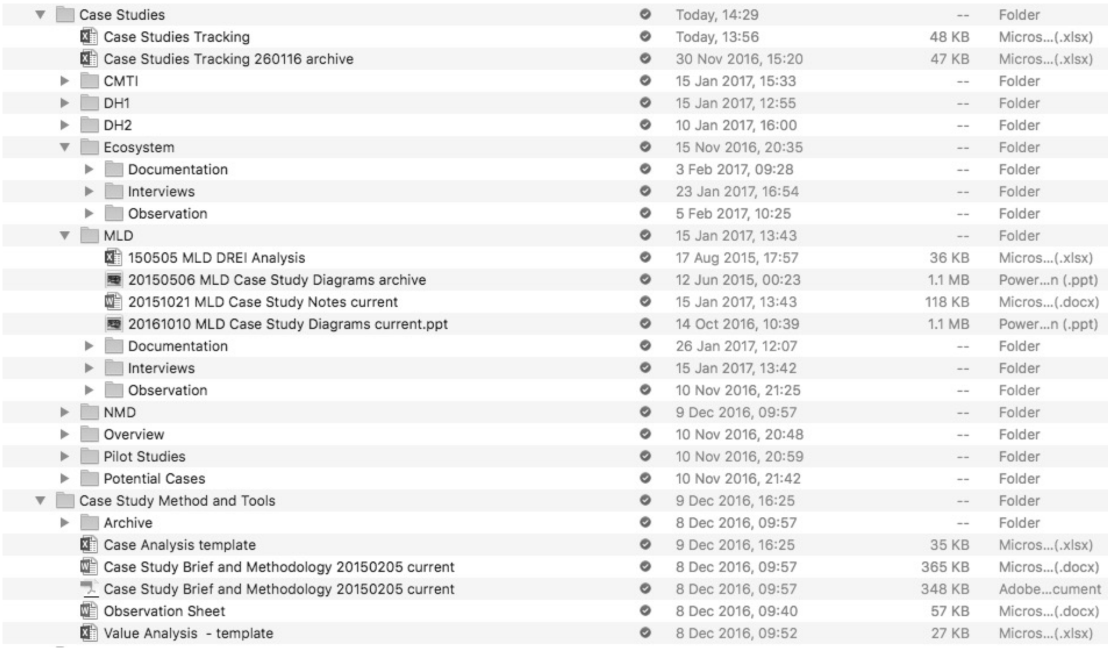

Figure 4-11 Example of data collection, storage and tool folders

Table 4-9 Summary of case evidence and sources

Case	Organisation and Innovation Description	CMT Domains	Interviews - with example interviewees and (N=) number	Number of Observations (O=) and private/ public documents (D=)	Summary of Case Key Activities and Status
NMD	New Innovation Unit in major pharma/med tech company developing an novel implantable medical device	BNI	R&D Head, Scientific Director, Head of Venture Fund, Business Dev Director, Alliance Partner (N=15)	External workshops (O=1) Business Plan, Board papers, White paper (D=31)	Internal venture in incumbent organisation. Major funding in place, with new governance board, alliance project underway and venture fund in place. Formed JV with major technology company. Established leadership position in field.
MLD	Start-up, developing AI/machine learning as a basis for screening, diagnosis and monitoring	BI	CEO, CTO, Medical Director, Investor, and Suppliers (N=15)	Board meetings, Technical meetings, Meetings with investors (O=16) Business Plan, Development Plan and Technical documents (D=25)	Start-up. In early development. Initial grants won and pilot trials completed. Development trials underway. First major investor in place and follow-up funding in late negotiation. On track to launch.
DH1	Innovation Unit in large healthcare provider developing mobile and digital health applications for a range of medical conditions	BI	Managing Director, Project manager, Board members and senior managers of their Suppliers (N=15)	Team meetings, Customer meetings, Project kick-off and review meetings (O=8) Business plan and Project review reports (D=26)	Internal venture in incumbent organisation (regional). Business plan for new venture in place, run as wholly owned subsidiary. Early projects delivered and launched. Increasing influence at national level.
DH2	Start-up developing wearable and digital health solutions	BI	Chairman, CEO, CTO (N=6)	None (O=0) Business plan, investment options (D=9)	Start-up, attracted limited initial funding (grants). In process of identifying investors. Unable to find in sufficient time and terminated.
CMTI	Incubator developing infrastructure and support for convergent medical technologies	BNI	CEO, Business Development Manager, Board Members (N=10)	Company workshops, Company conferences, Internal review meetings (O=6) Board paper, Internal review papers (D=11)	New venture in incumbent organisation. Board approval to develop full plans, with funding in place. Complementary investments in place. Range of ecosystem building activities underway.

4.6.6 Case Data Analysis

Case studies are individually reported in Chapter 6 and cross-case analyses (see Chapter 7) were used to identify wider themes, divergences and framework concepts. Although the data analysis did not occur in a linear fashion, it can be roughly divided into the following stages:

- Coding of evidence using the Exploratory Framework as starting point
- Developing coding breadth and depth as events are observed
- Seeking patterns within each case and developing potential explanations which are explored via additional coding
- Development of tentative models and frameworks for testing via interviews and further coding

Analysis of the Case Study evidence was undertaken using methods described by Miles, Huberman and Saldaña (2014) and for each case, initial coding approaches described by Saldaña (2013) were employed. Initial coding or provisional coding (Saldaña, 2013, p. 144), used factors from the exploratory framework as a starting point. At this stage *simultaneous coding* (Saldaña, 2013, p. 80) using both *descriptive coding* (Saldaña, 2013, p. 87) and *structural coding* (Saldaña, 2013, p. 84) was used, as evidence could be construed in several ways. In order better understand the nuances in the evidence sub-coding (Saldaña, 2013, p. 77) was used to break down the factors to consider detail (for example ecosystem related codes were sub-divided into more discrete codes covering understanding, dynamics, policy and institutions and, supporting and investing). As the research evolved some initial patterns and themes emerged. So, categories were developed (for example 'creating credibility', 'cooperating and integrating') using *pattern coding* (Saldaña, 2013, p. 209). These were then developed into themes and concepts (for example 'knowledge sharing', 'providing effective governance') typically using *causation coding* (Saldaña, 2013, p. 163). Finally, models were developed (for example 'searching', 'sense-making', 'selecting', 'shaping' and 'sustaining'). As the analysis evolved, later coding increasingly used *gerunds* (e.g., searching, selecting, managing etc.) or *process coding* (Saldaña, 2013, p. 96) as this permitted "a strong sense of action and sequence" (Charmaz, 2014, p. 120) to address the question of *how* organisations innovate. An example of the coding evolution is provided in Figure 4-14, Figure 4-15 and Figure 4-16.

Case data was analysed (coded and re-coded) on ongoing basis. As new themes emerged, explored, further literature reviews were undertaken to assist in pattern identification. Concepts were tested, including direct questioning of interviewees (for example, the lack of evidence for internal resistance in one case was addressed by asking the respondent if this was actually so, and if so, why?). This permitted more nuanced and in depth understanding of not only 'how' but 'why' events occurred, thereby strengthening the arguments for the proposed causal mechanisms.

As well as coding, analyses were undertaken to create a practical embodiment of Figure 4-3 and the 'working backwards process' of retroduction. Starting from described or observed events 'E', the relevant context 'C', the likely drivers or powers 'P' to infer the causal activity or process or object 'O'. Summarised as **ECPO**, the process used is schematically depicted in Figure 4-12.

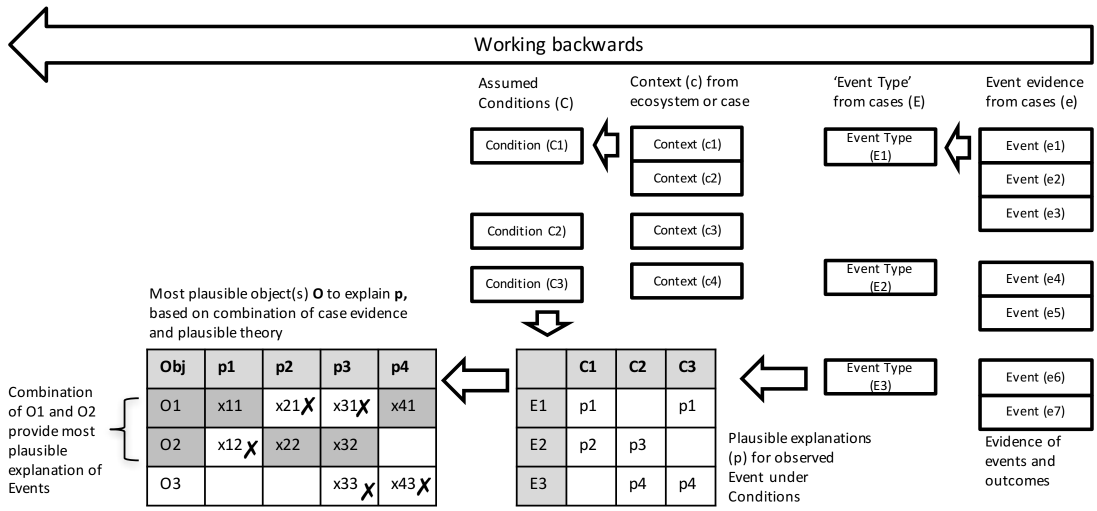

Figure 4-12 ECPO analysis process schematic

This analysis was conducted using an Excel spreadsheet. Relevant case events (e) were identified from the investigational framework, interviews, observations and documentation. Conditions or context (c) that might limitations or enablers to those events were identified from the prior ecosystem analysis (see later) and local conditions. Likely causal powers and liabilities for the organisation (p) were developed (i.e., what would the organisation be expecting to achieve or prevent?) and from these, likely mechanisms were postulated (x), which were then subject to analysis to ascertain if they were plausible and whether there was a supporting theoretical basis. The most plausible mechanisms were identified (o) and finally confirmed by identifying 'concretisation' or 'contextualisation' evidence in the form of a quote that directly supported the proposed mechanisms. The Excel spreadsheet template used for this process is shown in Figure 4-13.

As the analysis proceeded the initial codes were grouped into patterns that aimed to describe either a structure, process or intent (see Figure 4-14). The codes either built upon early coding or were newly created as concepts emerged. Further coding aimed to establish evidence for specific themes from the literature, for example the drivers for alliance formation (see Figure 4-15).

	Case: *ID*											
e	**Event - Inverview, Observation or Document (e) - identified from Case Summaries**	**c**	**Conditions or Context (in innovation ecosystem) (c)**	**p**	**Likely Causal Powers and Liabilities (tendencies) (p, l)**	**x**	**Possible Mechanisms (process, structure) (x)**	**Theoretical foundation**	**Plausible? Rationale**	**O**	**Suggested Object - Mechanism, process,**	**Contextualize**
e1	Observation - from case evidence - via investigational framework	c1	Ecosystem context - potential limiation from ecosystem analysis	p1	intent to overcome a noted limitation or enable an opportunity	x1.1	plausible mechanisms as derived from evidence and coding	support for this (key author / theory)?	is it plausible? And is there evidence to support it?	O1	refined plausible mechanism	direct evidence - document, observation or quote to support
e2	Action - from case interview via investigational framework	c2	other condition observed or evidenced in case (e.g. identifed by	p2	inferred organisational tendency, from prior activity, culture, interviewee comment	x1.2	other plausible mechanisms - alternatives?	support for this (key author / theory)?	is it plausible? N - reject, either unlikely or no evidence	o2	rejected plausible mechanism	no evidence
e3	Document - from case evidence via investigational											

Figure 4-13 Excel template for ECPO analysis to identify causal mechanisms

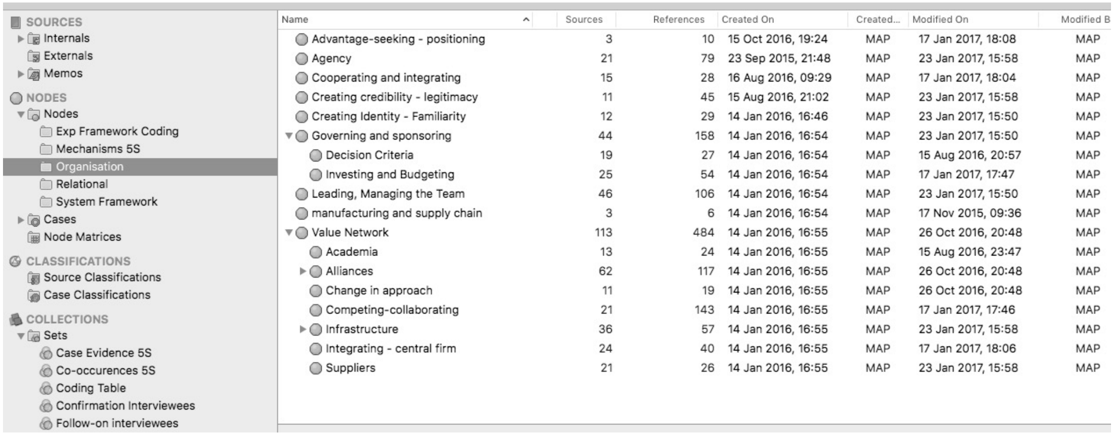

Figure 4-14 Example of development of pattern coding in NVivo

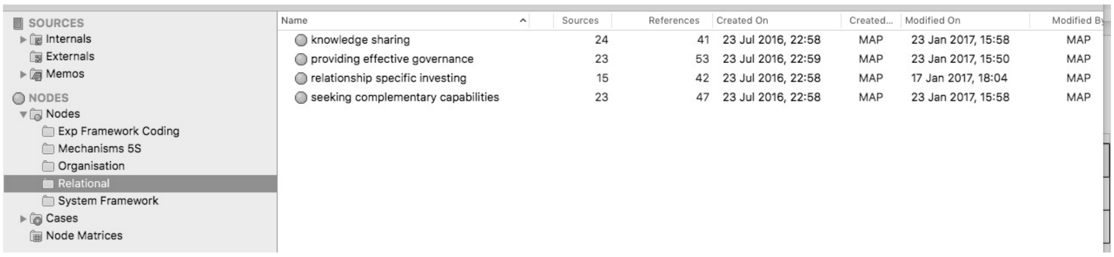

Figure 4-15 Example of development of thematic coding

As potential causal mechanisms were identified and developed in the ECPO spreadsheets by combining the context and potential objects (Vincent and Wapshott, 2014), these were also coded. These are examples of coding with *gerunds* which enabled a more action or activity orientated perspective (Charmaz, 2014), and are depicted in Figure 4-16. Causal analysis was further supported by multiple sources (Maxwell, 2012, 1992; Wynn Jr. and Williams, 2012; Yin, 2014) where a variety of data types and sources and analytical approaches are used. First, the data were collected from varying sources (i.e., semi- structured interviews, documentation and observation). Secondly, multiple data points within each source of evidence (e.g., multiple respondents with different roles or skills) were used, where the activation and operation of the causal mechanisms were derived from the perspective of multiple participants involved in certain innovation events.

As potential causal mechanisms were developed, so were alternative explanations, which are discussed with each case in Chapter 6.

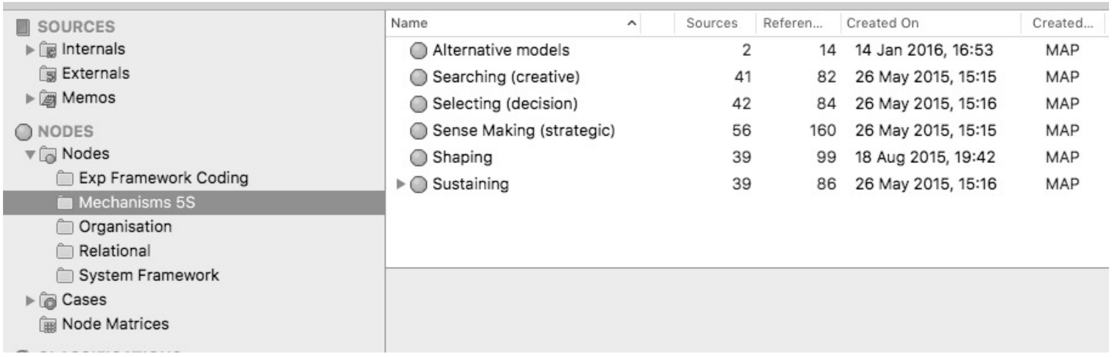

Figure 4-16 Example of development of *gerund*-based model coding

4.7 Methodological Rigour Considerations

Drawing on a set of criteria for evaluating methodological rigour suggested by qualitative research scholars in general (Guba and Lincoln, 1994) and critical realism scholars in particular (Healy and Perry, 2000), this section seeks to set out the strategies developed and used throughout the study to maximise its quality and rigour.

Healy (2000) identifies methods to judge validity and reliability in a realist paradigm. "*Six comprehensive and explicit criteria for judging realism research are developed, drawing on the three elements of a scientific paradigm of ontology, epistemology and methodology. The first two criteria concern ontology, that is, ontological appropriateness and contingent validity. The third criterion concerns epistemology: multiple perceptions of participants and of peer researchers. The final three criteria concern methodology: methodological trustworthiness, analytic generalisation and construct validity*."

Yin (2014) similarly identifies a number of criteria for case research validity, which have been derived and summarised as Table 4-10. In this study, the factual accuracy of the accounts (e.g., description of events) is achieved by a combination of the interviewees accounts, or multiple-interviewees accounts, combined with documentation and observation evidence. Furthermore, the participants' exact words are provided in direct quotations throughout the study where required. Additionally, to ensure that case interviewees viewpoints and evidence are accurately interpreted (interpretive validity), the key case findings have, in part, been shared with key participants to review and provide feedback.

Table 4-10 Case validity tests

Tests	Definition	Case Study Tactic
Construct Validity	To identify operational measures for the concepts studied	Use multiple sources of evidence, establish chain of evidence. Have key informants review draft case study report or extracts
Internal Validity	Seeking to establish a causal relationship, whereby certain conditions are believed to lead to other conditions, as distinguished from spurious relationships	Through pattern matching, explanation building, addressing rival explanations, and using logic models.
External Validity	Defining the domain to which a study's findings can be generalised	Use replication logic in multiple case studies, with relevant context. Define context for each case.
Reliability	Demonstrating that the operations of a study can be repeated with the same results	Develop case study process and database using tools such as NVivo database.

The criteria suggested by Yin have been expanded using criteria for CR studies (Healy and Perry, 2000) to address the ontology (i.e. recognising the research as ''world three' (Magee, 1985)), contingent validity (i.e. that causal mechanisms influenced by context (Pawson and Tilley, 1997), multiple perspectives are applied (Danermark et al., 2002), methodological trustworthiness (i.e., using a database and NVivo), analytic generalisation (Yin, 2014) and construct validity (Gibbert et al., 2008; Yin, 2014). The case write up also include examples of screens and evidence from the NVivo analysis to improve transparency (Bringer et al., 2004).

The approach is designed to address calls by innovation scholars, notably Garud et al (2013) to take a multi-level, longitudinal perspective, and to follow events implicating actors, artefacts, and institutions over time and, in addition to paying attention to the context, to understand the sub-text of agency.

5 Preliminary Research Findings

5.1 Preliminary Ecosystem Investigation and Framework Development

The aim of the preliminary research was to better understand the wider ecosystem and use this context to develop a framework for the case study investigation. To achieve this ecosystem wide interviews were undertaken to help define the boundary and the key issues that may impact innovation activities and practices.

Following initial interviews with a small expert group (known to the researcher as knowledgeable and interested in this field), snowballing was used to extend the search for participants. Interview data were continually mapped until, after 23 interviews, it was clear that only limited new information was emerging. By mapping the ecosystem actors identified in each interview, an initial map was constructed of the ecosystem. The ecosystem map, boundary and summary of key issues were then presented to four further interviewees, to help validate the boundary and preliminary findings. The interviewee data for this phase is summarised in

Table 5-1.

The interview data was analysed using the Gioia method (Gioia et al., 2012), via an Excel spreadsheet to sort and cluster data. First order coding was largely *in vivo* using 'concepts' identified by interview participants. These were then grouped and developed into second order themes; these themes were then further aggregated into broader 'dimensions'. An example of this analysis for one dimension is provided in Figure 5-1. This approach was completed for all coding references.

The emerging dimensions were then considered in the light of the implications for innovators and their capabilities (Table 5-2) which then provided a starting point for development of the exploratory framework.

The identified themes from the ecosystem interviews, via a process of abduction – inference derived from the induced findings (themes) and a review of relevant literature, were used to generate a list of expected capabilities and processes, for convergent innovation. This analysis is summarised in Table 5-3. From this analysis, the resulting Exploratory Framework (Table 5-4) was developed and used to identify topics for investigation in the case studies, clustered into thematic areas or 'factors'.

A final step was undertaken to check for alignment of this framework with key issues identified in the interviews to ensure that nothing had been 'lost' or filtered in the analysis.

Table 5-1 Preliminary ecosystem interviews

ID #	Interviewee Role	Organisation Type	Date	Approx. Interview Duration (mins)
ECO01	Senior Managers and Directors (4 people)	Incubator	03/02/2014	75
ECO02	Vice President	Major Healthcare Consultancy	10/02/2014	60
ECO03	Director	NHS Trust	12/02/2014	45
ECO04	Senior Executive	Major Diagnostic Company	18/03/2014	45
ECO05	Angel Investor and CEO	Angel Investor	17/04/2014	75
ECO06	Chairman	Private Equity	07/04/2014	60
ECO07	Partner	Investment Fund	07/04/2014	75
ECO08	Project Director	Academic Medical Research - University	07/04/2014	60
ECO09	CEO	Biotech	22/04/2014	45
ECO10	Vice President	Major Pharmaceutical Company	24/04/2014	75
ECO11	Non-Exec Director	Biotech	22/04/2014	60
ECO12	Senior Manager	AHSN - NHS	28/04/2014	60
ECO13	Partner	Health Media	08/05/2014	75
ECO14	CEO	Charity / Patient Group	13/05/2014	75
ECO15	CEO	Incubator	12/05/2014	90
ECO16	CEO	Biotech start-up	15/05/2014	60
ECO17	Head of Research	Health Economics	16/05/2014	45
ECO18	Technology Leader	Innovate UK	08/09/2014	30
ECO19	Partner	Corp Venture Capital	03/06/2014	60
ECO20	Senior Executive	MNC Pharmaceuticals	19/06/2014	60
ECO21	Senior Executive	MNC Pharmacy	14/07/2014	45
ECO22	CEO	Med Tech	21/07/2014	60
ECO23	Director	NHS Trust	29/07/2014	60
Confirmatory Interviews				
ECO24	CEO	Academic Innovation Unit	17/09/2014	60
ECO25	CEO	Biotech	23/09/2014	60
ECO26	Senior Manager	Regulator MHRA	23/10/2014	60
ECO27	Director	Med Tech Incubator	10/11/2014	60

	1st Order Concepts	2nd Order Themes	Aggregate Dimensions
11	Convergence seen as a threat	Evolving, heterogeneous system - several 'not obvious' entrants possible	The emerging ecosystem is not well understood, new agile entrants and new models are meeting risk averse and fragmented stakeholders
25	Apple, Google entry may open up options		
40	Very diverse groups - challenge getting them together		
55	Cross industry collaboration - Philips and Intel, MS		
56	Challenges from Apple, Google other 'tech'		
59	Key influencers not yet clear		
86	Public Health agenda not well represented		
91	Navigating different stakeholder agendas		
95	CCGs have ability to use service providers outside NHS.		
99	BUPA, Axa might take on new roles - payers and integrators like KP in USA		
106	Community Pharmacy to provide more services?		
136	CCGs can look outside Trusts		
150	Are pharma best positioned to deliver 'health care'?		
2	Industry rate change is slow	Industry is generally risk averse, with fragmented markets and low adoption rates	
9	Risk aversion in NHS		
15	NHS adoption- fragmented		
103	Markets all different, no pattern		
121	UK NHS opportunity, but highly politicised, fragmented and bureaucratic		
50	Big differences in how assessed, valued across markets	Customer models are different across countries	
85	Some markets (Germany) no reimbursement		
103	Markets all different, no pattern		
133	Markets are heterogeneous, so need different models		
27	Need wider engagement, cross sector	Understanding across industrial ecosystem is generally poor, resulting in missed opportunities	
34	Lots of poor value tech being developed, due lack of understanding		
40	Very diverse groups - challenge getting them together		
42	Getting Public funding interested in CMT		
44	Need better influencing network		
47	Need to create an ecosystem to support		
53	Need for hub or ecosystem		
82	R&D lots of duplication and reinvention		
91	Navigating different stakeholder agendas		
138	Make better use of AHSNs		

Figure 5-1 Example of 1st and 2nd order analysis leading to aggregate dimensions following the Gioia method

Table 5-2 Emerging 'dimensions' from preliminary ecosystem interviews

Emerging 'dimensions' from ecosystem interviews	Potential Implications for innovators' capabilities
Knowledge and capabilities are diffuse (and spread widely). Diverse approaches and duplication of effort are evident.	Search approaches may need to be different, and direct comparisons of capabilities may be difficult.
The emerging ecosystem is not well understood, new agile entrants and new models are meeting risk averse and fragmented stakeholders	Significant knowledge management and learning are required upfront of any investment or development decision
The emerging ecosystem contains organizations with wide variations in Culture and Capabilities	As well as technological and capability differences, the value network partners are likely to have different cultural attitudes and norms
There is, typically, a lack of Customer Engagement and understanding of future Business Models	Given the lack of clarity in potential business models, developing long term alliances with clear value capture mechanisms may be challenging
New assets carry higher risk and have less understood investment decision criteria	Governance and decision criteria need to reflect the uncertainty and inferred risks
Public R&D Funding and venture capital investment are not well developed for the ecosystem, and these funders perceive new risks	The lack of public funding may result in 'holes' within the 'ecosystem' knowledge base
The Value Networks and Supply Chains will require new alliances and new models	Existing and established decision models and approaches may need to be modified.
Regulation, Legal and IP issues are more ambiguous in the emerging ecosystem	This adds different risks to the innovation and value network
There is a lack of Infrastructure and support organizations	Which may result in a lack of certain specific capabilities and capacities within the ecosystem

Table 5-3 Abduction to translate ecosystem themes into Exploratory Framework

Factor	Ecosystem themes (from Table 5-2)	Literature Sources Abduction	Example Response in terms of capabilities and processes
Ecosystem and Market understanding	Knowledge and capabilities are diffuse (spread widely). Diverse approaches and duplication of effort are evident. The emerging ecosystem is not well understood, new agile entrants and new models are meeting risk averse and fragmented stakeholders	(Hacklin, 2005; Hacklin and Wallin, 2013; Phaal et al., 2011; Rikkiev and Mäkinen, 2013; Stieglitz, 2003)	Firm undertakes activities to map and understand the ecosystem to keep pace with its evolution.
Stakeholder Management	There is a lack of Customer Engagement and understanding of future Business Models. The emerging ecosystem contains organizations with wide variations in Culture and Capabilities	(Ackermann and Eden, 2011; Donaldson and Preston, 1995; Rowley, 1997)	Map and engage stakeholders through the life-cycle of the development process to facilitate progress, and evolve relationships over time.
Governance	New assets carry higher risk and less understood decision criteria	(Cooper, 2008, 1990; Rikkiev and Mäkinen, 2013; Salomo et al., 2010)	Active senior management support and engagement in investment decisions. Adequate knowledge for project selection and progression through objective decision gates.
Gate Criteria	Regulation, Legal and IP issues are more ambiguous in the emerging ecosystem	(Cooper, 2008, 1990; Gronlund et al., 2010)	Objective Go / no go decision criteria to determine progressing to next phase, that consider external capabilities and paths.
Process	No direct evidence	(Holahan et al., 2014)	A process or methodology exists to guide process development and quality management
Risk Management	Public R&D Funding and VC Investment are not well developed for the ecosystem, and funders perceive new risks	(Hulbert et al., 2008; Kayis et al., 2007; McNeil et al., 2010; Rikkiev and Mäkinen, 2013; Zhang and Yongbo, 2011)	Risk management processes are in place to address patient and user safety risks, and the combination of technological risks, product integrations risks and business and commercial risks
Project Team	No direct evidence	(Meyer, 1993; Patanakul et al., 2012; Sivasubramaniam et al., 2012)	The core team has leadership, expertise and experience, and balances autonomy, accountability and empowerment within the governance framework
Alliance Partners	The Value Networks / Supply Chains will require new alliances and new models	(Dickson et al., 2006; Hacklin and Wallin, 2013; Ireland et al., 2002; Lewrick et al., 2012; Rothaermel and Deeds, 2006; Soda, 2011)	Inter-organizational co-operation via clarity in objectives and scope. Accessing capabilities through alliance partners, adopting different alliance management approaches to different partners.
Support infrastructure	The is a lack of Infrastructure and Support organizations	(Moore, 2005; Peltoniemi and Vuori, 2004; Rikkiev and Mäkinen, 2013)	Firm builds and makes use of ecosystem and infrastructure to complement capabilities and support development culture

Table 5-4 Exploratory Framework for investigation of convergent innovation

	Factor	Example

Ecosystem Factors		
F1	**Ecosystem and Market understanding**	Firm undertakes activities to map and understand the ecosystem to keep pace with its evolution and develop it.
F2	**Stakeholder Management**	Map and engage stakeholders through the life-cycle of the development process to facilitate progress, and evolve relationships over time.
Business Model Factors		
F3	**Customer Engagement**	Routines and capabilities to engage early in the development process with customers to inform product/service design and the potential business model options
F4	**Business Model development**	Map and understand the links between the business model and the required activities and capabilities.
F5	**Value Attributes**	Map and understand key value creation and capture steps (linked to business model)
Execution Factors		
F6	**Governance**	Active senior management support and engagement in investment decisions. Adequate knowledge for project selection and progression through objective decision gates.
F7	**Gate Criteria**	Objective Go / no go decision criteria to determine progressing to next phase, that consider external capabilities and paths.
F8	**Process**	A process or methodology exists to guide process development and quality management
F9	**Risk Management**	Risk management processes are in place to address patient and user safety risks, and the combination of technological risks, product integrations risks and business and commercial risks
Value Network Factors		
F10	**Alliance Partners**	Inter-organizational co-operation via clarity in objectives and scope. Accessing capabilities through alliance partners, adopting different alliance management approaches to different partners.
F11	**Project Team**	The core team has leadership, expertise and experience, and balances autonomy, accountability and empowerment within the governance framework
F12	**Support infrastructure**	Firm builds and makes use of ecosystem and infrastructure to complement own capabilities and to support development of innovation culture

5.2 Ecosystem Understanding

During the preliminary ecosystem interviews analyses were undertaken using the previously developed PBSRDC method to understand the ecosystem boundaries, structures and dynamics. The boundary determination used the method depicted in Figure 4-6, as the first step in understanding the nascent ecosystem. The approach to identifying the structures and dynamics were as depicted in Figure 4-7 and Figure 4-8

5.2.1 System Mapping and Determination of System Boundaries

The methodology followed that summarised in Chapter 4. During each interview data was captured based upon actors and key issues identified, and translated into a 'map'. An example from one such interview (ECO12) is shown in Figure 5-2. As actors were identified by the respondent they were drawn on or highlighted, as were any key challenges, relationships and opportunities. These along with interview notes were captured for all preliminary interviews.

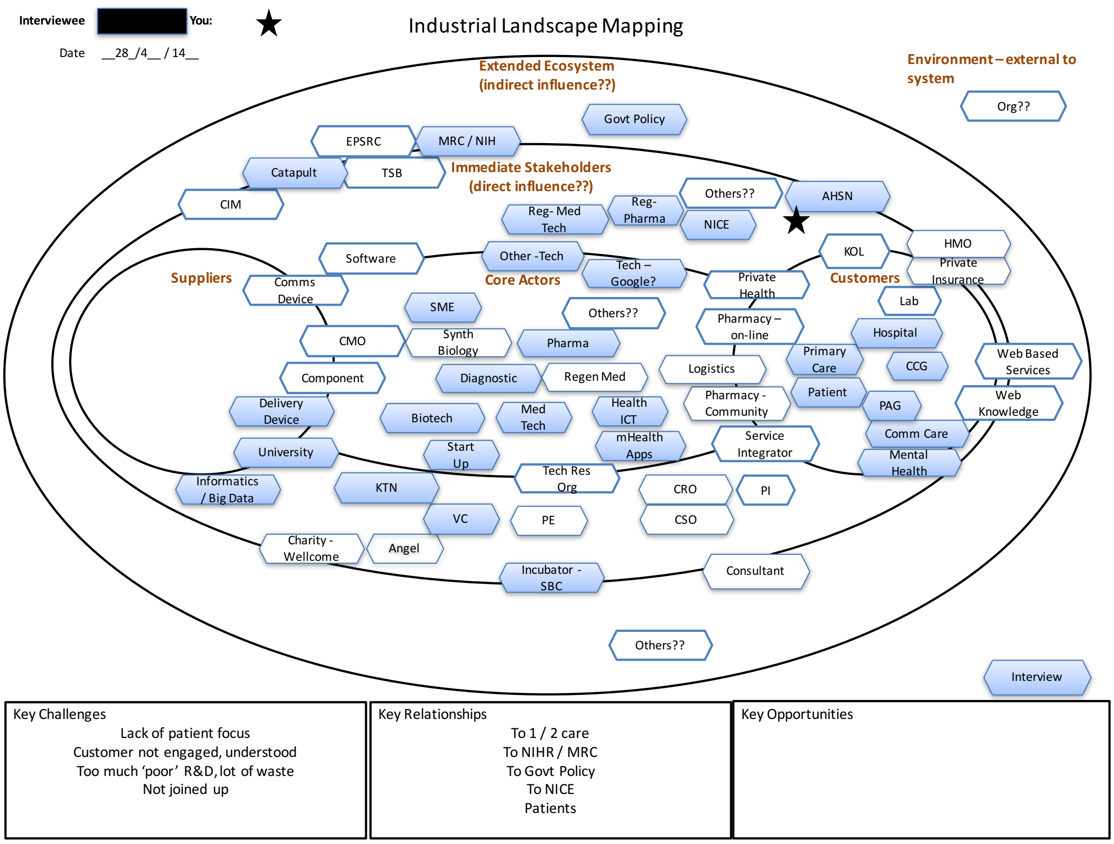

Figure 5-2 Example of evidence capture from ecosystem interviews

The frequency of identification (by interviewees and stakeholders) and perceived 'interest and influence' was used as a guide inclusion (or exclusion) in the ecosystem boundary (see Figure 5-3).

Cluster	Actor Group	Interviewee Identifed (Count)	Rank	Interest (I1) H M L	Influence (I2) H M L	Continuity (C) L M S	ICC (= I1xI2xC)	ICC + Count	Include in Ecosystem ?
Producers	Diagnostic	17	1	3	2	1	6	23	Y
Producers	Pharma	17	1	2	3	2	12	29	Y
Producers	Med Tech	16	3	3	3	3	27	43	Y
Producers	Health ICT	16	3	2	3	2	12	28	Y
Providers	Hospital Trust	15	5	2	2	2	8	23	Y
Producers	Biotech	14	6	2	2	3	12	26	Y
Producers	Startup/ SME	13	7	3	1	2	6	19	Y
Producers	Other Tech	12	8	2	1	1	2	14	Y
Knowledge	University	12	8	2	2	1	4	16	Y
Infra/Support	SBC/Biocity	11	10	2	2	3	12	23	Y
Funding	VC	11	10	2	3	2	12	23	Y
Payer	CCG / NHS E	10	12	2	3	3	18	28	Y
Policy	DoH/OLS	9	13	1	2	2	4	13	Y
Reg	NICE	9	13	1	1	2	2	11	Y
Producers	mHealth Apps	9	13	3	1	2	6	15	Y
Reg	MHRA Ph	8	16	2	2	3	12	20	Y
Funding	Charity / CIC	8	16	2	2	2	8	16	Y
Reg	MHRA/NB	7	18	2	2	3	12	19	Y
Res Fund	MRC/NIHR	6	19	2	2	2	8	14	Y
Res Fund	AHSN	6	19	2	2	2	8	14	Y
Suppliers	Device	6	19	2	1	2	4	10	Y
Suppliers	Informatics	6	19	2	1	2	4	10	Y
Suppliers	CRO	6	19	2	1	2	4	10	Y
Suppliers	Other Tech	6	19	2	1	2	4	10	Y
Providers	Primary Care	5	25	2	1	2	4	9	Y
Providers	Mental H	5	25	2	1	3	6	11	Y
Suppliers	Software	5	25	2	1	2	4	9	Y
Suppliers	Web Services	5	25	2	1	2	4	9	Y
Producers	Regen Med	5	25	2	1	3	6	11	Y
Funding	PE	5	25	2	2	2	8	13	Y
Patients	Patient Grp	4	31	2	1	2	4	8	Y
Providers	Comm Care	4	31	2	1	3	6	10	Y
Infra/Support	KTN/Catapult	4	31	2	1	2	4	8	Y
Producers	Integrators	4	31	3	2	3	18	22	Y
Funding	CorpVC	4	31	2	2	2	8	12	Y
Policy	PHE	3	36	1	1	3	3	6	Y
Advisor	Consultant	3	36	1	2	2	4	7	Y
Providers	HMO	3	36	2	2	2	8	11	Y
Providers	Comm Pharmacy	3	36	2	2	2	8	11	Y
Res Fund	TSB/IUK	2	40	2	2	2	8	10	y
Payer	Private Ins	2	40	1	1	1	1	3	n
Suppliers	Comms Tech	2	40	1	1	1	1	3	n
Suppliers	Tech Res Org	2	40	1	1	1	1	3	n
Producers	Synth Biology	2	40	2	1	2	4	6	n
Funding	Angel	2	40	1	1	1	1	3	n
Reg	CQC	1	46	1	2	2	4	5	n
Res Fund	EPSRC	1	46	1	2	1	2	3	n
Providers	Labs	1	46	1	1	1	1	2	n
Suppliers	Component	1	46	2	1	1	2	3	n
Suppliers	CSO	1	46	1	1	1	1	2	n
Suppliers	Logistics	1	46	1	1	1	1	2	n
Knowledge	TTO	1	46	1	1	1	1	2	n
Funding	Inv Funds	1	46	1	1	1	1	2	n
Funding	Crowds	1	46	1	1	1	1	2	n
Advisor	OHE	0	55	1	2	1	2	2	n
Advisor	KOL	0	55	1	2	1	2	2	n
Providers	Hosp Pharmacy	0	55	1	1	1	1	1	n
Providers	Online Pharmacy	0	55	1	1	1	1	1	n
Suppliers	OMES	0	55	1	1	1	1	1	n
Suppliers	CMO	0	55	1	1	1	1	1	n
Producers	Ind Associations	0	55	1	1	1	1	1	n

Figure 5-3 Analysis of ecosystem boundary – using frequency, interest and influence identified during interviews

The decision to include or not include is still subject to researcher subjectivity, but the process allows a degree of objectivity and data to support the decision. On completion of the preliminary interviews, a different group of stakeholders was used to confirm the proposed ecosystem boundary (together with a minor refinements).

As part of the process a preliminary map was developed (Figure 5-4), which evolved during the interviews.

5.3 Exploratory Framework Testing via Pilot Cases

Before starting the actual Case Studies, two preliminary cases, based upon literature and desktop analysis, were used to review the Investigational Framework, and to assess whether it was appropriate and complete.

Two pilot case studies were run, both P1 and P2 used information from recent projects with reasonable access to information. This enables the Exploratory Framework to be reviewed in a more realistic setting and aimed to address two questions:

- *Does the framework help identify relevant issues?*
- *Are there relevant issues outside the framework?*

These two pilot cases used are summarised in Table 5-5.

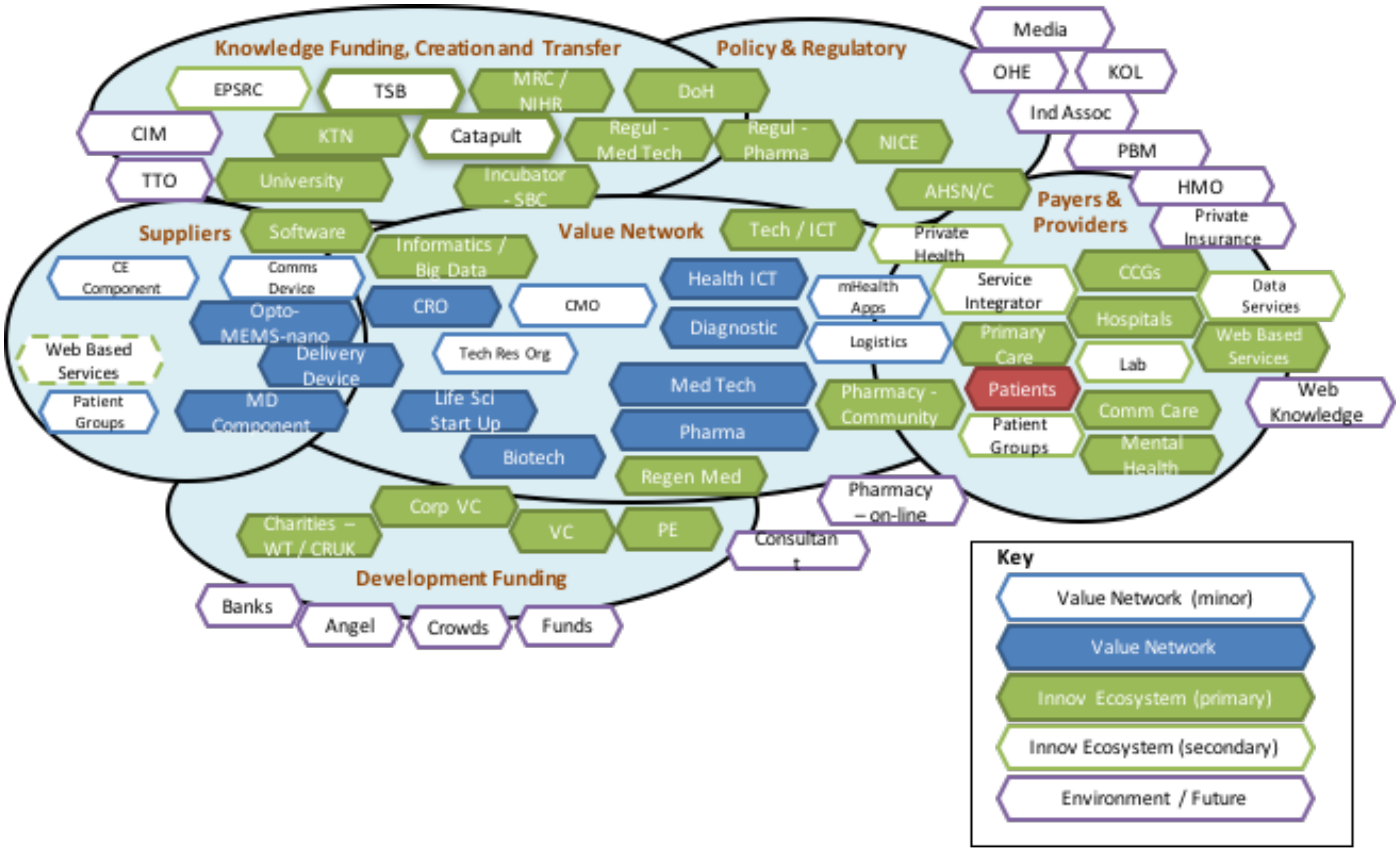

Figure 5-4 Example of partial ecosystem mapping (and tentative boundaries)

Table 5-5 Summary of pilot cases P1 and P2

	Case P1	**Case P2**
'Case' firm	Novartis	GSK
Scale: MNC or SME	MNC	MNC
Product (P) or Platform (T) based or infrastructure (I)	P	P
Therapeutic	Y	N
Med Tech / Diagnostic	Y	Y
Health ICT	Y	Y
Access to value network and stakeholders	*Web, Literature based*	*Web, Literature based*
Issues identified with Exploratory Framework	*Minor changes to wording of Factors*	*Minor changes to wording of Factors. Re-clustering of Factors to a more logical structure.*

5.3.1 Case P1 (Pharmaceutical MNC plus Device and Telemedicine)

Case: Complementary Technologies to support a new respiratory product

- **Description** – A desktop / literature study of the development of delivery device and digital health solutions and services to complement a new pharmaceutical product and support patients to improve health outcomes.
- **Process and Risk Management-** there was insufficient information or evidence to draw any significant conclusions.
- **Governance –** there was insufficient information or evidence to draw any conclusions.
- **Stakeholder Engagement –**there was limited information that indicates that the lead firm were addressing stakeholder engagement widely. A field study acknowledged the challenges in stakeholders perceptions (García Lizana, 2013) but there are no details on how this was being addressed.
- **Business Model –**There is clear evidence from an interim report on a field study (García Lizana, 2013) that business models were a challenge, in fact one aim of the study was to investigate ways to address this.

The case observations versus the exploratory framework are summarised in Table 5-6. There was insufficient information in the public domain to complete this Case Study to my satisfaction, but it did however highlight issues in several areas including the business model, the challenging perceptions of different stakeholders and the diversity of ecosystem partners.

5.3.2 Case P2 (Pharmaceutical MNC developing complementary diagnostic)

Case: Complementary Diagnostic Product

- **Description** - Development of a new diagnostic product by a MNC pharmaceutical company, with alliance partners, which complements the company's existing therapeutic products and franchises.
- **Process and Risk Management -** The firm had well-established NPD processes but needed to develop a 'modified NPD process' to manage the project. There was recognition that the design process and regulation was different, which resulted in some changes in risk management approach. Although existing process provided an acceptable framework, the differences in regulation, technology and supply chain meant specific processes were inappropriate in some areas and therefore revised.
- **Governance -** The existing high-level governance processes were used. But due to the faster nature of the project timelines, mechanisms were needed to address response time. Ad hoc reviews were used, which resulted in 'less complete governance' and special teams needed to be formed to undertake technical governance.
- **Stakeholder Engagement -** Was sporadic and usually for specific interventions. Generally successful in identifying the need to operate different processes for: regulation, CRM, pack artwork, logistics/supply chain and servicing. Engagement was generally later than ideal.
- **Business Model -** The business model was understood to be different. A separate business unit was formed to address this. The overview of the business and commercial model were completed, but in depth analysis of the actual business model and how and when value would be captured were only addressed late in the project. This resulted in fundamental errors in the revenue model and in a major lack of confidence (by the governance review) in the commercial model; a key contributor to the decision to terminate.

The case observations versus the exploratory framework are summarised in Table 5-7.

This Case Study highlighted issues with the business model challenges and the need to modify processes and governance to manage the different technologies. The study also points to a need for senior sponsorship and governance support within the organisation.

Table 5-6 Case Study P1 - Observations on the framework factors

	Factor	Observations.	Conclusion
F1	**Ecosystem and Market understanding**	Novartis appear to be particularly active in this area with a number of deals and announcements that indicate intent to engage in the wider ecosystem. Recent announcements with Proteus (Proteus, 2014, 2010) and Google (Novartis, 2014). The study itself is addressing key ecosystem challenges. Lack of interoperability, different perceptions of HCPs and patients.	There is evidence to support the existence of this Factor
F2	**Stakeholder Management**	Key stakeholders in individual markets are engaged (as markets are heterogeneous). Evidence of similar programmes across Europe in Scandinavia, Ireland as well as Spain.	Some evidence of this being put in place. But insufficient to draw conclusions
F3	**Customer Engagement**	Some evidence based upon on-going EU study.	Implicitly addressed in the EU study (see below).
F4	**Business Model development**	Potentially requires a new Business Model. Novartis sponsoring, funding several studies to address BM challenges ongoing, due to read out late 2014 (Fundacio Ticsalut, 2012; García Lizana, 2013).	Implicitly acknowledged in the EU study (see below). They have identified a clear challenge here, but do not yet have solutions.
F5	**Value Attributes**	This is identified as a challenge, EU study is addressing this. These are reported in the European Innovation Partnership site (García Lizana, 2013) •	Evidence this is recognised and being addressed, but is not yet in place.
F6	**Governance**	No direct information on governance of project. Formally managed through EU funding.	Insufficient evidence to draw conclusions
F7	**Gate Criteria**	No data	Insufficient evidence to draw conclusions
F8	**Process**	No data	Insufficient evidence to draw conclusions
F9	**Risk Management**	No data	Insufficient evidence to draw conclusions
F10	**Alliance Partners**	Novartis plays active role in funding, sponsorship and but researchers are independent. Key partners: Novartis (Switzerland), Sosei (Japan), Vectura (UK) Alliance partners in UK (device), UK (telemedicine software), Spain (field studies)	There is evidence this is occurring. Novartis are using a variety of different approaches to manage partners and studies.
F11	**Project Team**	No data	Insufficient evidence to draw conclusions
F12	**Support infrastructure**	No data	Some evidence of this being put in place.

Table 5-7 Case Study P2 - Observations on the framework factors

	Factor	Responses	Conclusion
F1	**Ecosystem and Market understanding**	Source: Competitor landscape mapping Regular updates on competitive landscape were undertaken (roughly every 6 months) as the field was changing fairly rapidly. Customers (Lab directors) and external experts were regularly engaged in the technical requirements. Regulatory landscape was well mapped. As was emerging regulation. Good understanding of overall market, key customers etc from database/market research.	Evidence that this was partially in place. Good knowledge of competitors but less so for other stakeholders
F2	**Stakeholder Management**	Engagement with several key stakeholders (notified Bodies, labs, LIS vendors, logistics providers) and consultants. But not directly with regulators. (MHRA / FDA).	Some evidence of this being put in place.
F3	**Customer Engagement**	Source: User Needs document Input to technical and functional requirements was in place. Initial engagement with potential users in labs to define technical and operational requirements. Follow up meetings with users to define specific supply chain and service requirements to enable value creation to be confirmed. Meetings with LIS system vendors to define interface requirements. Value capture activities conducted very late, resulting in change in commercial model. Target markets and pricing changed late in project.	Some evidence of this being in place. Developed for product design, technical and to get logistics input. Less so for commercial model.
F4	**Business Model development**	Known to require a new Business Model.	Evidence need for new model exists but not fully in place.
F5	**Value Attributes**	Value capture via 'reagent rental' business proposed, but this changed later as changes in accounting practice made some aspects unacceptable. Model still ultimately relied on main revenue generation via consumable sales. To achieve sales each customer (Trust) required to do own evaluation, resulting in significantly delayed commercial revenue stream, changing commercial plans. It was clear (in hindsight) that the explicit revenue / capture process was not understood in the launch markets.	Confirmed as 'absent'. Failure to manage this is seen as major contributor to failure.
F6	**Governance**	There were changes to governance. Initial plan was to use existing governance, but it became apparent this was not going to work (lack of expertise, and frequency of reviews). An alternative review mechanism was put in place, that permitted a more dynamic approach, but was less rigorous.	Evidence this was in place. But need some refinement to address project / technology needs.
F7	**Gate Criteria**	Established criteria used for major review gates.	Evidence this was in place.
F8	**Process**	Used existing NPS process as overarching process, then developed more customised process to address specific	Evidence this was in place.

	Factor	Responses	Conclusion
		needs of Med Tech.	
F9	**Risk Management**	Source: Project reviews Technical risks were tightly managed with milestone payments to alliance partners linked to discharge of risks.	Confirmed. In place for technical and integration. Failure to manage business model risk is seen as major contributor
F10	**Alliance Partners**	Source: Contract Agreements Main Alliance partner managed via a detailed contract. Contract needed updating due to financial concerns at partner. Main instrument supplier managed closely as technical risks high. Cartridge manufacturer relied on relationship with senior leader as product represented small revenue stream (supplier mainly in Consumer Electronics) Sample device was 'off shelf' item with minor customisation, not closely managed but resulted in contractual issues. Examples of different approaches being used. Alliance partners in UK (device), UK (telemedicine software), Spain (field studies)	Evidence of this being put in place. A range of different approaches was used. The main Alliance partner was seen as a significant risk and the management evolved to take account of those risks.
F11	**Project Team**	Experienced team drawn from across R&D, manufacturing and commercial. Some team members from outside normal R&D (eg bioinformatics, physics). Team supplemented with external consultants. Expertise also brought in from Consumer (who has CE marking knowledge).	Evidence team had wide experience and expertise and was supplemented where necessary.
F12	**Support infrastructure**	No external infrastructure used. Business Unit joined BIVDA (trade association) but relied on Alliance partners for their network. Started to develop own 'ecosystem' from Alliance partners, potential partners and experts. Internal ecosystem developed from staff with expertise in specialist technologies and from staff with Med Tech/CE marked product regulation. Focussed input from external experts. Used recognised TRO/ (P) to help technical integration, but no partnerships in commercial environment. Used range of business leaders with similar new business, '*intrapreneurial*', convergent challenges to identify ideas and challenges. But not all were acted upon.	Some evidence this was being put in place.

5.3.3 Conclusions

The analysis in Table 5-6 and Table 5-7 indicate that the proposed framework has utility in investigating convergent innovation cases. During the pilot studies, only small refinements made to framework wording, but not the overall structure or factors developed during abduction were essentially unchanged. The pilot cases therefore confirmed the usability of the exploratory framework. The revised version of the Exploratory Framework, used for case studies, is included in the Case Protocol in the Appendices, Appendix A2 – Case Study Protocol (extract).

6 Case Studies

6.1 Introduction

The Phase 2 research consisted of five in-depth and longitudinal case studies together with continued data collection in the emerging ecosystem. The findings from each of these are discussed in the following sections.

Case Context – Emerging Ecosystem - ongoing ecosystem review to understand context.

Case 1 - CMTI – medium sized incumbent, an incubator organisation providing 'ecosystem' for innovators and looking to move into convergent medical technologies

Case 2 - NMD – a novel R&D unit within a major pharmaceutical company. Developing a new class of therapeutics based upon convergence, by combining opto-micro-electromechanical systems (O-MEMS) and digital technology with therapeutics.

Case 3 - DH1 – an innovation unit within the NHS developing digital health solutions for patients and providers.

Case 4 - MLD – a start-up developing a novel diagnostic, based upon machine learning

Case 5 - DH2 - a start-up developing a novel medical device and digital health tools.

6.2 Case Context – Innovation Ecosystem

6.2.1 Introduction

The ecosystem was nascent and evolving, but, as previously identified, provides important ongoing context for the cases studies. As a result, ecosystem interviews and analysis continued to ensure that contemporaneous information was available during the case period. The evidence consists of the 27 preliminary ecosystem interviews (described in Chapter 5 and summarised in Table 6-1) and a further twelve ecosystem interviews, together with observations (at meetings and events) and documents. Details of further interviewees are provided in Appendix A4.

Table 6-1 Innovation ecosystem data sources

Data Sources	Details
Preliminary Ecosystem Interviews	27 interviews of senior managers and business leaders
Further Ecosystem Interviews	12 interviews of 11 senior managers and business leaders (see appendix A4)
Observations	11 Conferences, Meetings and Workshops
Academic, Business Press and Industry documents	28 Public documents and papers

6.2.2 Findings

The interviews focussed mainly on institutional actors, as the preliminary research identified institutional and infrastructure gaps. During the case research the top-level ecosystem did not evolve significantly, but there was developing understanding of the sub-systems, which are addressed in the following sections.

System Structure and Relationships

The top-level map (Figure 6-1) was then developed using a combination of interview data and public sources, to produce maps of sub-systems. The structured was developed, and extended, from similar value chain mapping by Srai (Kumar et al., 2013; Srai and Alinaghian, 2013; Srai and Christodoulou, 2012), but with actors clustered by type. These provide more detail and enable the identification of some processes, causal links and relationships. Where possible they were discussed and verified with interviewees. Example sub-system maps are provided in Figure 6-2 to Figure 6-7. One identified feature is that many relationships are more complex than any high-level mapping would suggest. This finding reinforces the view that better understanding of relationships is key in understanding the ecosystem and innovation options.

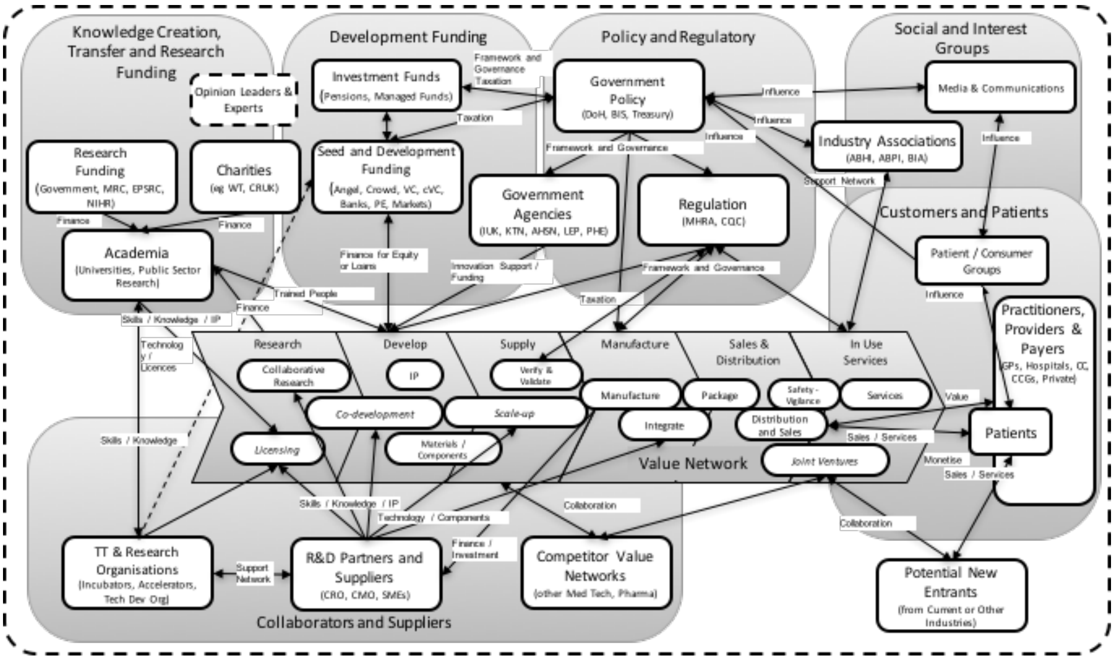

Figure 6-1 High-level innovation ecosystem

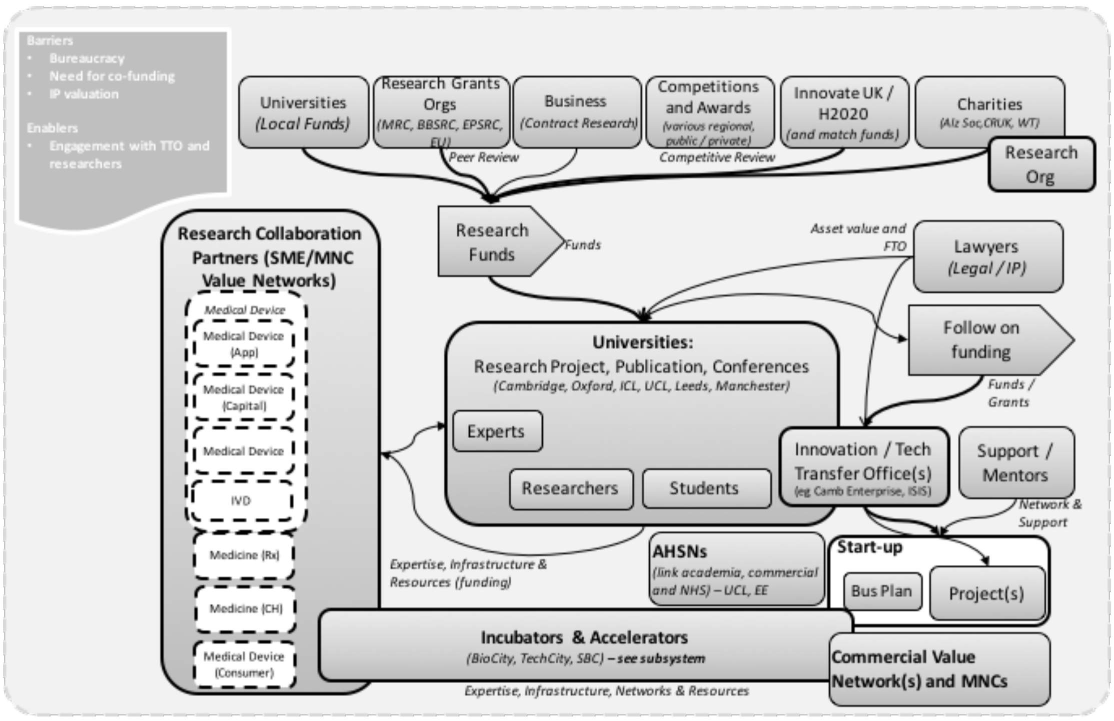

Figure 6-2 Knowledge creation and transfer ecosystem

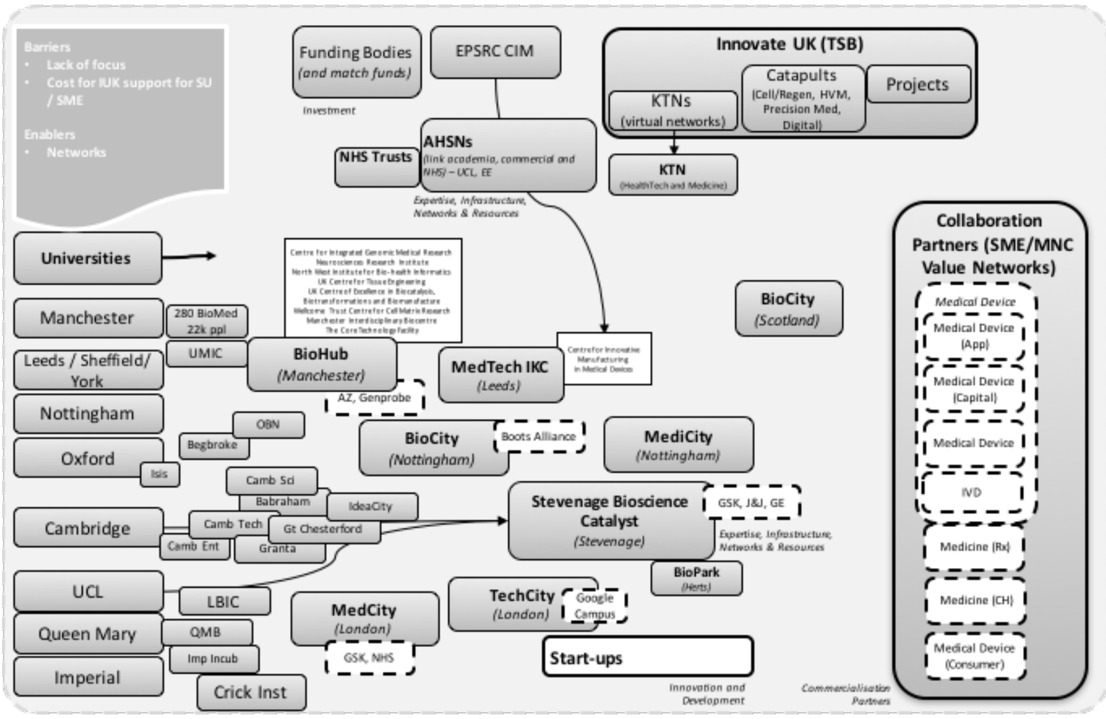

Figure 6-3 Incubators and accelerators ecosystem

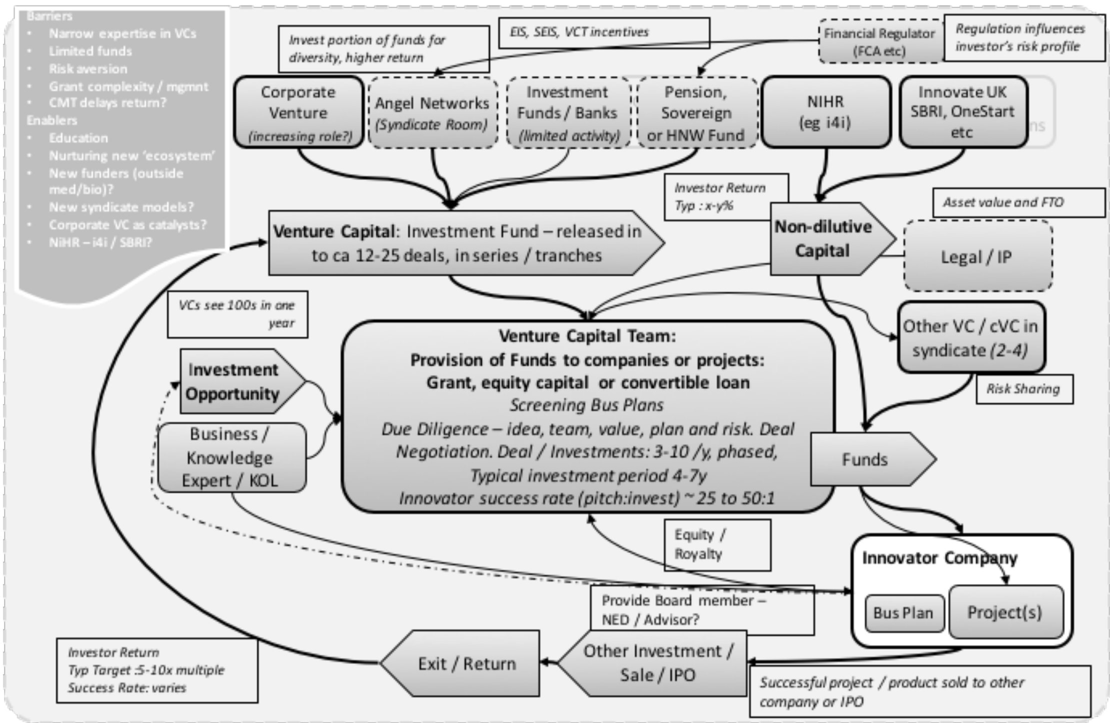

Figure 6-4 Investment and development funding ecosystem

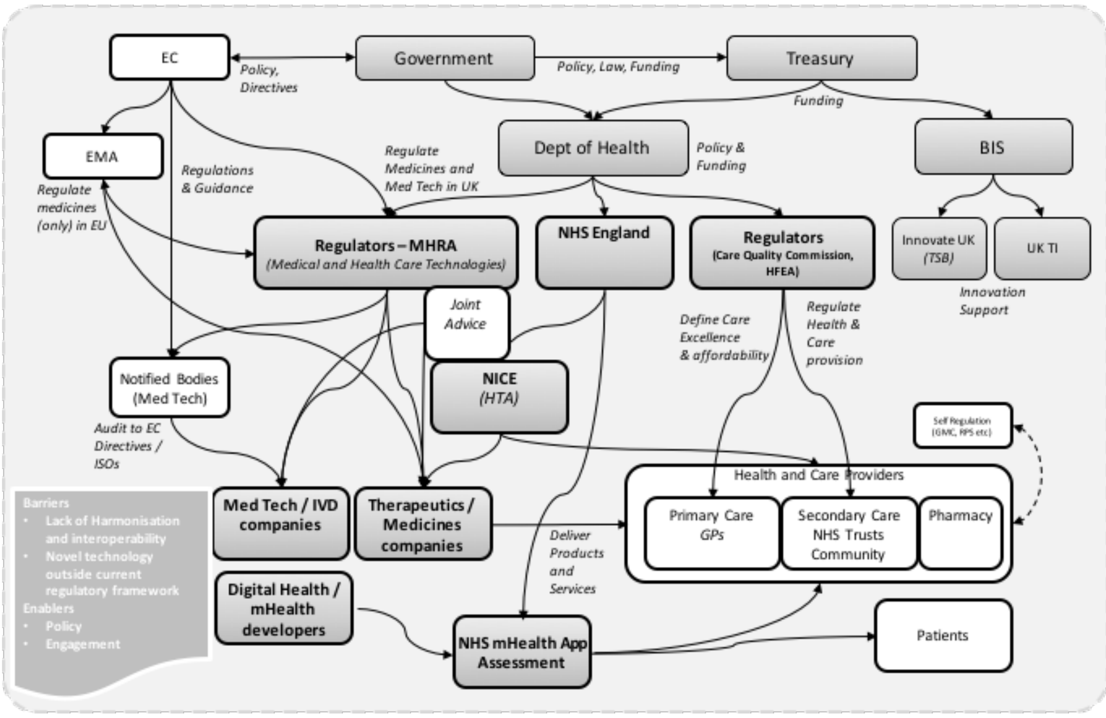

Figure 6-5 Policy and regulation ecosystem

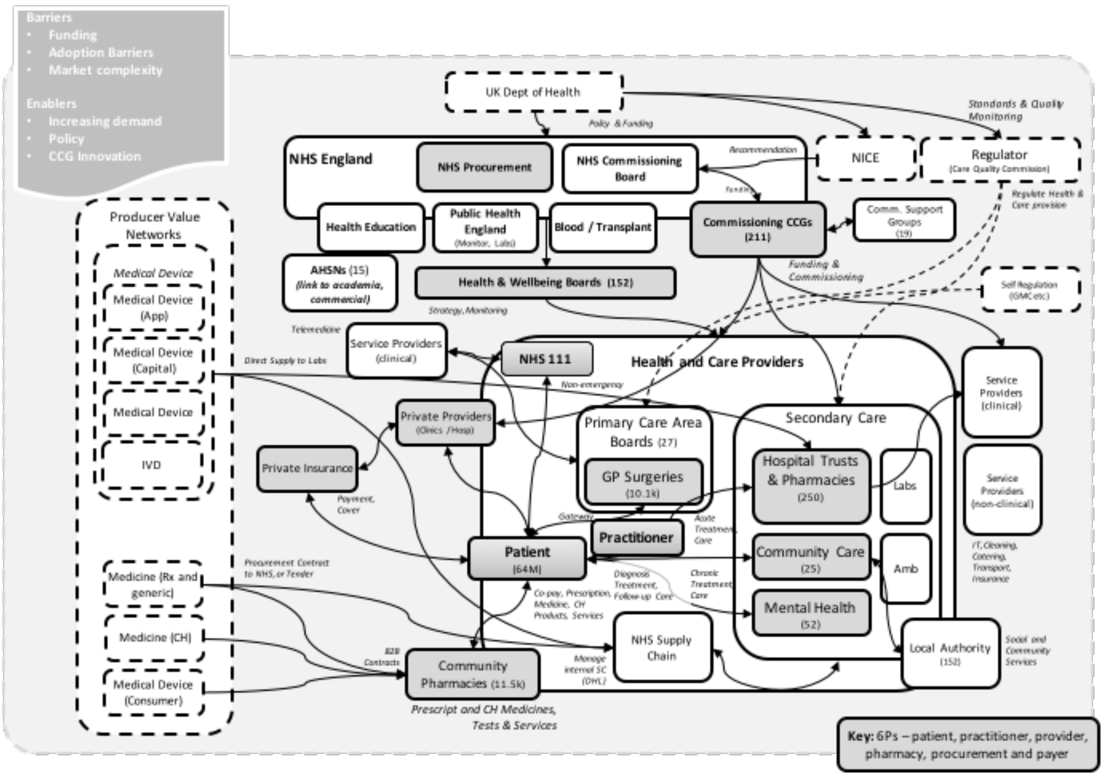

Figure 6-6 Health and care delivery ecosystem

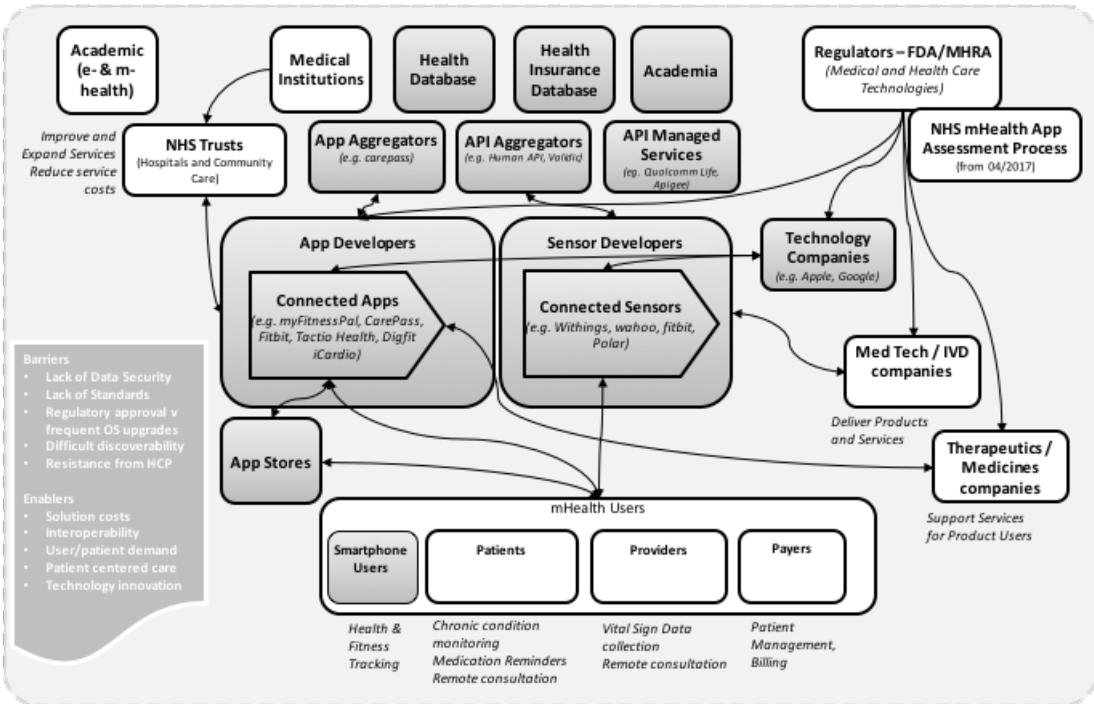

Figure 6-7 Digital and mobile health ecosystem

Ecosystem Dynamics and Co-evolution

A combination of interviews and literature sources were also used to identify ecosystem dynamics and evolution. Technology roadmaps (Phaal et al., 2011; Probert et al., 2003) were used to help articulate the key trends and patterns in the ecosystem (See Figure 6-8). The source references for these diagrams are included in **Error! Reference source not found.**. The roadmaps take PESTLE analysis, using political (P), economic (E), social (S), technological (T), legal (L), and environmental (E) considerations, as a starting point. The likely products and services, and the underpinning technology convergence required to support these products are then added.

The main themes identified from this analysis (the headline themes from the roadmap in Figure 6-8) were as follows:

- From PESTLE analysis:
  - Growing and Ageing Population
  - Increase in Chronic diseases (e.g. diabetes, respiratory, cardiac and cancer)
  - Healthcare Policy evolution
  - Regulatory reforms and evolving standards
  - Intellectual Property and Tax incentive changes
  - Access to Seed and early development funding
  - Access to Venture Funding

- Resulting in Product and Services:
    - New Integrated Healthcare and Service providers
    - Convergence enables new products and services in fields such as: diagnostics, precision medicine, regenerative medicine, digital health and 'cyber' health
- Underpinned by the following technologies:
    - Digital technologies, engaging and enabling communities
    - "Big Data', artificial intelligence and machine learning and analytics, to identify patterns in complex data
    - High precision 3D imaging, to improve understanding
    - Sequencing (DNA) and new biomarkers, enhancing disease understanding
    - Nanotechnology and new materials, enabling new sensor and implant devices
    - Additive manufacturing, enables personalisation
    - Synthetic biology toolkits, create new disease modulation possibilities
    - Cell-based technologies, as a step towards cures
    - Greater precision drugs, improve efficacy, at reduced risk

Issues Identified in the evolving Innovation Ecosystem

Initial issues and challenges in the ecosystem were identified in the preliminary research (see Chapter 5). The follow-on interviews, observation and documents, and subsequent mapping and trend analysis identified several additional context considerations, which are summarised in Table 6-2. Of these new emerging 'implications' only the ambiguity around regulation and assessment of digital and mobile technologies appeared to have direct influence on cases. BREXIT emerged relatively late in the research period and raised issues for one innovator around access to funding, but had little or no immediate apparent impact on other cases.

Table 6-2 Emerging 'dimensions' from further ecosystem interviews

Emerging 'dimensions' from ecosystem	Potential Implications for innovators'
Creation of Precision Medicine (PM) Catapult by Innovate UK to support innovation in this field	Provides single focus point and mapping of PM ecosystem.
Investment funding remains a challenge, but a few new funds are emerging	Innovators may need to look outside UK for follow on funding
NHS stopped their App assessment process and are replacing via new scheme (going live April	Uncertainty over digital health solutions and how assessed, but new process provides

2017)	greater clarity
NICE and MHRA providing joint reviews for novel technologies and innovations, where existing guidance is limited	Opportunity to engage and identify technical and economic expectations.
Accelerated Access Review for NHS	Aims to provide more 'joined-up' approach and adoption opportunities for innovators.
Delays in adoption of new EU medical device regulations	Increased uncertainty but proposed regulations bring requirements close to US FDA, so simplify in long term.
Unclear how some technologies such as 3D additive manufacturing of prosthetics and regenerative medicine might be regulated in future (FDA looking to 'validate' the design process)	Implications for how design is conducted. As interim measure innovators should engage FDA Division developing draft guidance.
Greater clarity of what EU / FDA accept as an 'App' and what constitutes a medical device. Software as a Medical Device (SaMD) now accepted.	Increasing regulation, but greater clarity on requirements
BREXIT referendum makes investment and regulatory picture less certain	Need to consider contingencies in both funding and regulatory requirements

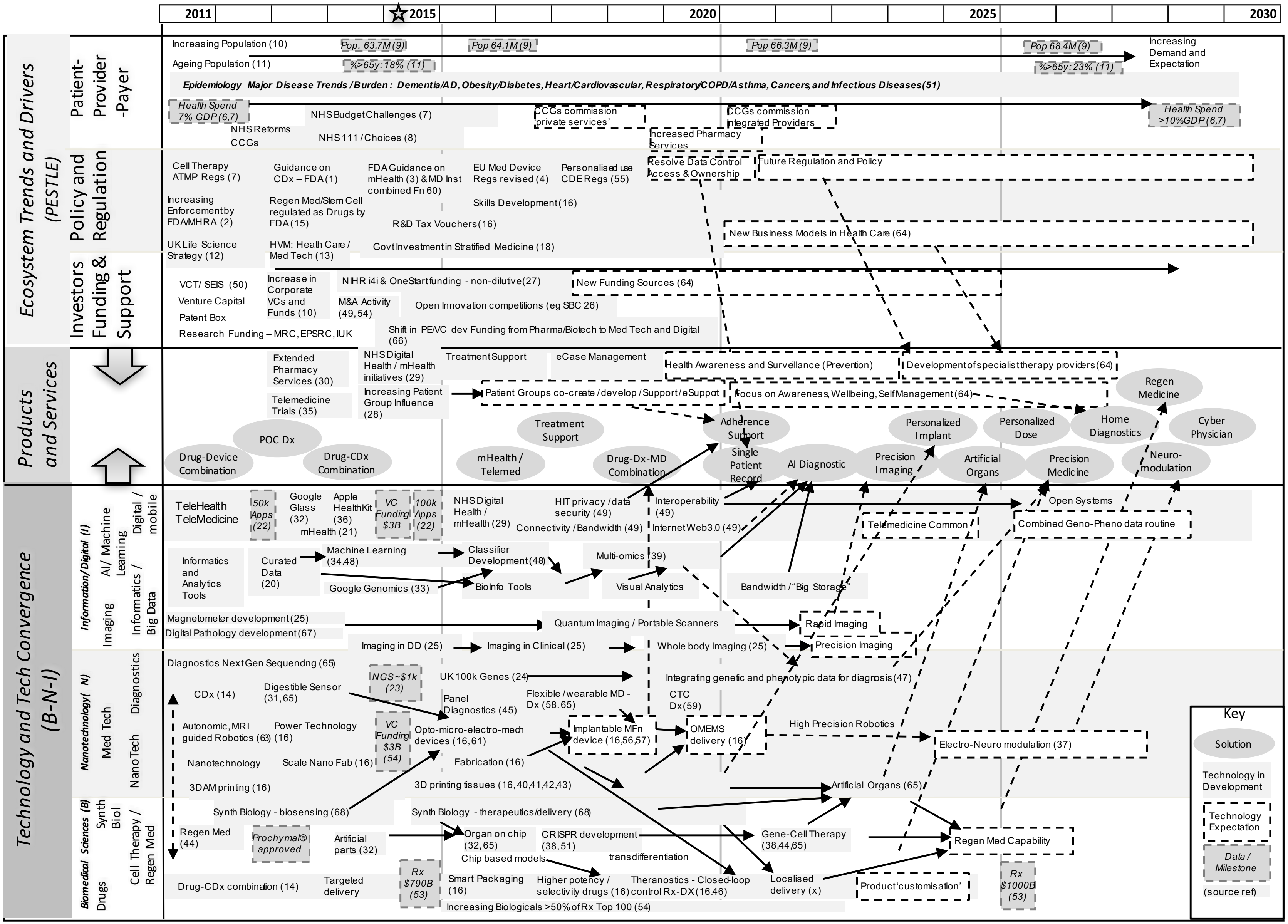

Figure 6-8 Trends and evolution within healthcare innovation ecosystem

6.3 Case 1 – CMTI

6.3.1 History and Background

The venture is an incumbent innovation incubator working with 'start-ups' in biomedical sciences, typically with biotech and medical device companies. The focus of CMTI is to provide an ecosystem to support innovators, with a combination of facilities, expertise, investors and value network partners. Their aim was to 'catalyse' convergent medical technologies.

The venture started in January 2014, with a proposal to develop a 'convergence' capability, during one of their Open Innovation Summits. By May 2014, the start of the case research, CMTI had begun the process of trying to understand the ecosystem and potential partners. Firstly, the proposed venture did not fit their existing technology structure and network. The venture was aiming to support convergent technologies with a major investment program for which the incumbent organisation and current partners had little expertise. There was limited understanding of the potential business models and value. It therefore required CMTI to work with a diverse range of stakeholders, many of whom were unknown at the outset of the venture.

During the case period, the CMTI venture progressed from an idea, and via exploration to an outline concept, which was then focussed and developed, in the process they built a new network and nascent ecosystem and, via external funding, obtained commitment for a major investment in convergent medical innovations.

The research followed the venture for two years (until June 2016), so provides evidence from close to its inception through early development and a major milestones whereby significant investment and commitment was made. A summary timeline, highlighting key events in the case history is provided in Table 6-3.

Table 6-3 Case CMTI study key events

Date	Event
Jan 2014	Announce interest in 'convergence' at their open innovation (OI) summit
Mar 2014	Univ. College London (UCL) move into facility
May 2014	Case started. Initial discussions with Sagentia to review recent developments in convergence (have documents)
Jun2014	Hold workshop with some board members and interested parties (attended and observed).
Q3 2014	Conduct exploratory searches in the field – what is going on, who is working in it. Aim for top level understanding and whether opportunity exists.
Aug 2014	Internal Convergence team meeting with some external input (attended and observed). Agree to follow up searches and exploration. Aim is to provide input to a Phase 2 Strategy, but timing not finalised.
Jan 2015	Chair (and one of convergence 'visionaries' steps down due to ill health. Open Innovation summit conference – also discussed 'convergence and CMTI role or potential roles, engaging with diverse audience.
Q2 2015	Some delays in pulling next phase team together. Other priorities.
Jul 2015	Hold meeting at CMTI with diverse stakeholders to discuss options and CMTI potential engagement (attended and observed)
Q3 2015	Start process to gather and codify data on convergence areas. Focussed on Precision Medicine, Nano Technology, Digital, Big Data Analytics, Cell Therapy / Regen Medicine (have documents)
Aug 2015	Summarise review of convergence as input to Board paper – review covers science, companies, academia, institutes, research councils and investors. Output for draft Phase 2 Board paper (documents obtained). Engaged in negotiations for regen therapy capability at CMTI
Sep 2015	New Chairman appointed. Plan for 'convergence' updated. Focus on Regen, Bioelectronic and Precision Med, plus facility design options. Pitched to Wellcome Trust as potential investors and Board members.
Oct 2015	Contribute to 'Castell' article on Precision Medicine
Nov 2015	Construction of regen therapy facility started.
Q1 2016	Conduct more systematic review and study via interviews – formally reported monthly. Exploring wider stakeholders and opportunity area.
Apr 2016	Phase 2 Board Paper developed. [XXX] Technology moves to Facility.
May 2016	Formal decision at Board to commit to Phase 2 – with focus on Regen Medicine, Precision Medicine and Bioelectronics, in addition to existing biotech capabilities.
Dec 2016	Begin progress of convergent (Future Healthcare' capabilities at CMTI.

6.3.2 Case Evidence

Case Research followed the methodology developed in Section 4. During the case study, data was collected from interviews, observations and, from public and company documents (obtained under a confidentiality agreement). A summary of the interviewees, observations and documents accessed is provided in Table 6-4 and the interviewees sources are summarised in Appendix A4. Direct observation at meetings and workshops with innovators, investors and other key stakeholders also provided evidence of practices and capabilities. All data was securely stored on a confidential cloud server and uploaded into NVivo CADQAS software for analysis.

Table 6-4 Case CMTI study data sources

Data Sources	Details	Aspects studied
Case Interviews	10 interviews of 8 senior managers and business leaders over the case period, totalling over 11 hours (ranging from 30 mins to 90 mins).	Identification of patterns in capability change; manifestations of skilful agency and existing innovation capabilities
Internal strategic documents	11 Business Plans, internal Board and governance reports, and project status reports	Identification of patterns in broader capability change; and engagement with ecosystem
Observations	6 Workshops, project meetings, and internal team meetings	Observation of innovation practices and working with partners
Company Website	News updates, thought-pieces and open calls for input from 2014 to 2016.	Public information on the new ventures and engagement
Academic, Business Press and Industry documents	2 Public documents including Reports and papers CMTI contributed too, other documents on initiatives related to ecosystem	Examples of engagement with others, and driving forces elsewhere in ecosystem

6.3.3 Analysis

Coding followed the process described in Section 4. Initial coding was based upon the exploratory framework. The main events identified in the exploratory framework under factors F1 to F12 were summarised and used as input to subsequent coding, and then subject to the ECPO analysis to identify plausible mechanisms. The ECPO analysis for this first case (Table 6-5) is included below but for subsequent cases (and clarity) these analyses are included in the Appendices.

During the case, simple ecosystem maps were also developed based upon interview evidence and interviewee input.

Table 6-5 ECPO Analysis for Case CMTI

ECPO Analysis Case: CMTI

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
e1	Use of OI Events and seminars	c1	Poor understanding of opportunity and ecosystem	p1	Ensure CMTI had access wider ecosystem actors	x1.1	Crowdsourcing for inputs and solutions	Chesbrough - open innovation	Yes - well established mechanism	o1, o6	Strategic Search via multiple engagements, meetings to build relations. Creating Visibility and Legitimacy in field	*Multiple evidence at CMTI events and website (observed at events on 01/1214, 02/12/14, 06/01/15, 28/02/15, 21/10/15, 11/01/16)*
						x1.2	Events as 'showcase'	Kotter, Eisend? publicity v marketing	No, clear intent in agenda and approach to engage and seek input, not self-advertise			
e2	Workshops and Meetings with innovators, developers, funders and charities	c1	Poor understanding of opportunity and ecosystem	p2	Need to identify collaborators, sources of knowledge to ensure solutions were appropriate and acceptable.	x2.1	Systematic search	Garud, Pandza - strategic search	Yes - there is a need to identify where knowledge resides, it is new to the organization	o1, o2, o6	Strategic Search (both local and distant - using structured and snowball approaches)	11/11/15 CMTI-2: "We've run events like the Cell Therapy and Regen Med event, which involved 2 tenants and the rest were a national audience, maybe 70 people. Then we've run convergence events and summits, so it's in 100s. Tomorrow we have a cell therapy investors event."
		c2	Ecosystem of potential parters did not exist at the outset. Increase network awareness across ecosystem			x2.2	Use network to extend search (snowball)	Goodman - snowballing Rosenkopf / Nerkar- distant knowledge	Yes - it is a novel area, so need approach to scan 'distant' knowledge and sources	o1, o2, o6	Strategic Search (both local and distant - using structured and snowball approaches)	11/11/15 CMTI-2: "Tomorrow I'm at the 3rd Annual EU Advanced Therapies Investor Day in London. It involves GE, CTC, BIA, Lonza, Panmuir Gordon (solicitors), its invite only at RIBA. It will open up a new network for us."
												20/05/15 CMTI-3: "I think one of the things that has come out of today is the need to get that better clarity. So we are going to probably do some more research. We are thinking of engaging even more widely. "

ECPO Analysis Case: CMTI

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
		c3	Specific knowledge and technology gaps across ecosystem			x2.3	Interchange of idea and challenges - sense-making	Gioia, Weick, Daft and Lengel - sense-making	Yes - as knowledge is new, there is a need to exchange and challenge to build understanding	o2, o6	Sense-making via diverse stakeholder interactions and an integrating role	11/11/15 CMTI-2: "We recently attended a bioelectronics meeting with Wellcome Trust, that [...] organised. It involved GSK, Wellcome, EPSRC. One interesting things was that in UK, there was no one, in academia, that saw themselves with a bioelectronics' label, but when you got underneath and found out what they were doing, they were doing BE related work. So the labelling and branding are important, and affect communication and understanding."
						x2.4	Events as 'showcase'	Kotter, Eisend? P publicity v marketing	No, clear intent in agenda and approach to engage, not self-advertise			
e3	Open innovation and 'crowdsourcing' projects	c3	Specific knowledge and technology gaps across ecosystem	p3	Need to engage users in identify (real) problems and potential solutions	x3.1	Interchange of ideas and challenges - to create known/ unknown knowledge domains	Gioia, Weick, Daft and Lengel - sense-making	Yes - as knowledge is new, there is a need to exchange and challenge to build understanding	o2, o6	Sense-making via diverse stakeholder interactions and an integrating role	"We also plan to have another Summit in April 2016, on Open Innovation and convergence."
		c1	Poor understanding of opportunity and ecosystem									11/11/15 CMTI-2: "But we see it as natural extension of our OI agenda, so we don't differentiate. "
e4	Mapping stakeholders and understanding the emerging ecosystem	c1	Nascent ecosystem, key actors not established, knowledge gaps in ecosystem	p4	Need to develop wider understanding and stronger ecosystem links to support decision making and identify long term partners	x4.1	identifying potential partners, future value network and blocks to progress	Gioia, Weick, Daft and Lengel - sense-making	Yes - as knowledge is new, there is a need to exchange and challenge to build understanding	o2, o9	Sense-making via diverse stakeholder interactions and an integrating role	CMTI Database: (via GoogleDrive - access provided) contains summary of key organisations, convergence interest, contacts and links to further information
												11/11/15 CMTI-2: [referring to above database] "Each of us, adds to it as we come across academics, tech companies etc. We've been working on it for 8-9 months. [CMTI-5] often adds to it. It gives us a sense of who the players are and what's going on. Its not just UK though. "
												05/10/15 CMTI-3: "It's fairly structured. We started with people we know. But are now expanding the interviews, talking to their suggested contacts.... We want to extend our search beyond the usual suspects. We want some diversity. We also want to complete it by the end of the year so we can focus in 2016."

ECPO Analysis Case: CMTI

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
												17/11/15 CMTI-6: "It's fairly informal, understanding the issues and challenges, across clinical, regulatory, supply china, financing, technology. We want to understand where [CMTI] can help overcome problems. With at UK level or with [CMTI] facilities."
e5	Business model mapping exercises	c4	Business models in ecosystem not generally established	p5	Identify viable and sustainable model to deliver value and meet vision -	x5.1	Need to develop a viable model for the venture, sources of funding / income not clear	Gioia, Weick, Daft and Lengel - sense-making	Yes, evidence that diversity of stakeholders and broader legal, IP issues make the decision challenging.	o4, o7	Sustain- identify solutions that ensure venture is viable	17/11/15 CMTI-6 "Its more about understanding the landscape. Trying to identify who, where, what and importantly what the potential value is. We are still in the storming phase organisationally. We want to understand the value of being linked to [CMTI], from their perspective. We also know that this is potentially an area where first followers will get the real benefit, particularly in things like regulatory. Whoever goes first will have challenges."
e6	Mapping value from different stakeholder perspectives - 'persona'	c5	Lack of understanding of 'value' for new technologies and 'convergence'	p6	Desire to add value and contribute to outcomes	x6.1	Want to ensure solutions are valuable to others	Sarasvathy, Garud, Sydow - shape	Yes - examples, of seeking to create value from several perspectives and where they can create future value	o2, o4, o7	Understanding and then trying to Shape - a viable model and advantage	11/11/15 CMTI-2: "… recently asked to speak at Wellcome Trust. We positioned it as 'Future of Healthcare' rather than 'convergence'. We've also positioned convergence as a natural extension of what we are doing on open innovation."
						x6.2	Want to ensure value is understood in nascent ecosystem		Yes - evidence of desire explore value widely			17/11/15 CMTI-6: "The other issue of course is EU versus USA. They are different from a regulatory view and a market. So what may work in one might not work in the other. That changes the value. Particularly things like the reimbursement model. Its not clear how it will be funded. That's not just for things like Apps, but all technologies where there isn't a clear product exchange and selling model."
e7	Development of own view of 'convergence' and implications	c2	Lack of understanding across stakeholders	p7	Need to create common understanding to move investment and partnerships forward	x7.1	Need for clarity in vision	Gioia, Weick, Daft and Lengel - sense-making	Yes, seeking to position role in emerging ecosystem - as connectors, integrators	o2, o7		11/11/15 CMTI-1: "As you know I see the Future Healthcare agenda as about convergence. We've been working on it for 18 months or so. Its about bringing IT, electronics, engineering to the biosciences to deliver ne solutions to biological problems. If you think traditionally its about bringing the pill, the diagnostics, the data and devices all together. "

ECPO Analysis Case: CMTI

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
e8	Building governance and oversight on existing approaches	c6	There are some established processes, and criteria.	p8	Make minor modifications to suit contact and increase objectivity in decision making	x8.1	Need to engage and bring 'on board' key stakeholders	Ries - efficiency / lean	Yes - partial	o8, o10		11/11/15 CMTI-1: "To develop our thoughts, we have been bringing, as you know, experts, panels together, running workshops. As we are asking the Board for £50M (...) we need evidence, its not just us saying this and we are not trying to create 'just another science park', we want to drive an Open Innovation agenda. Thankfully our Board agree. "
e9	Refining internal processes to address 'convergence' - use small teams, external support, mini-conferences, conduct different searches	c7	The established processes or criteria are not always suitable	p8	Need to maintain momentum to secure funding, but also be agile and efficient	x9.1	Need agile process to deliver recommendations in an efficient way and address key risks	Shape - Sarasvathy, Garud, Sydow	Yes, moved to frequent meetings with ecosystem actors, and monthly updates to accelerate knowledge and option generation	o8, o10	Shape - legitimacy-seeking	Evidence in 'Convergence' Monthly Reports 2016 (accessed) - CMTI has moved to more regular meetings with, for exmaple: MRC, NIHR, Genomics England, Illumina, Medtronic, IBM, Boston Scientific, Roche. Then conducts internal review on feedback.
								Selection - experiential learning	Yes - needed to refine and focus decision criteria	o3, o10	Selection, experiential	
						x9.2	Need to improve processes	Dynamic capability - Teece et al	Partial? - some experiential learning, but no evidence of systematic SST.	o9	Evidence of range of small changes, across several processes. More driven by 'design' of management, who are clear a different way is needed	Observations
								Ambidexterity - Birkinshaw et al	Partial - no evidence of significant range of capabilities across organisation	o9		

ECPO Analysis Case: CMTI

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
						x9.3	Desire to be creative and develop 'own' solutions	Amabile - Creativity	No, whilst evidence looking for creative solutions, they appear happy to use existing tools where they work			
e10	Internal Business Plan regularly refined	c4	Business models in ecosystem not generally established	p5	Identify viable and sustainable model to deliver value and meet vision	x10.1	Business Model is to engage, identify problems and solutions, create IP and develop offerings that can then be delivered by others (for royalty) or license to other providers	Selection	Yes, partial - the key elements of required model are understood	o3, o10	Selection, Sustain	12/05/14 CMTI-1 "Probably a bigger concern is focus. Given the complexity and lack of understanding, it would be easy to step in and step into the wrong place. Equally you cannot cover it all. So we will need to think about how we focus. [CMTI] is interested. But initially the play is probably building on existing strengths in neurodegeneration, cell therapy, maybe bioelectronics .... But with others on board that may change."
				p9	Initial models too ambitious, defined as more information obtained	x10.2	Unsure as to what is best option, diverged at first, but then refined, as engaged to build understanding	Wieck - sense making	Yes,	o2, o8, o10	Sense-making - experiential learning process	17/1/15 CMTI-6: " … so we wanted to understand their position and plans so we can look to build synergies or help plug the gaps. Add value and avoid reinvention."

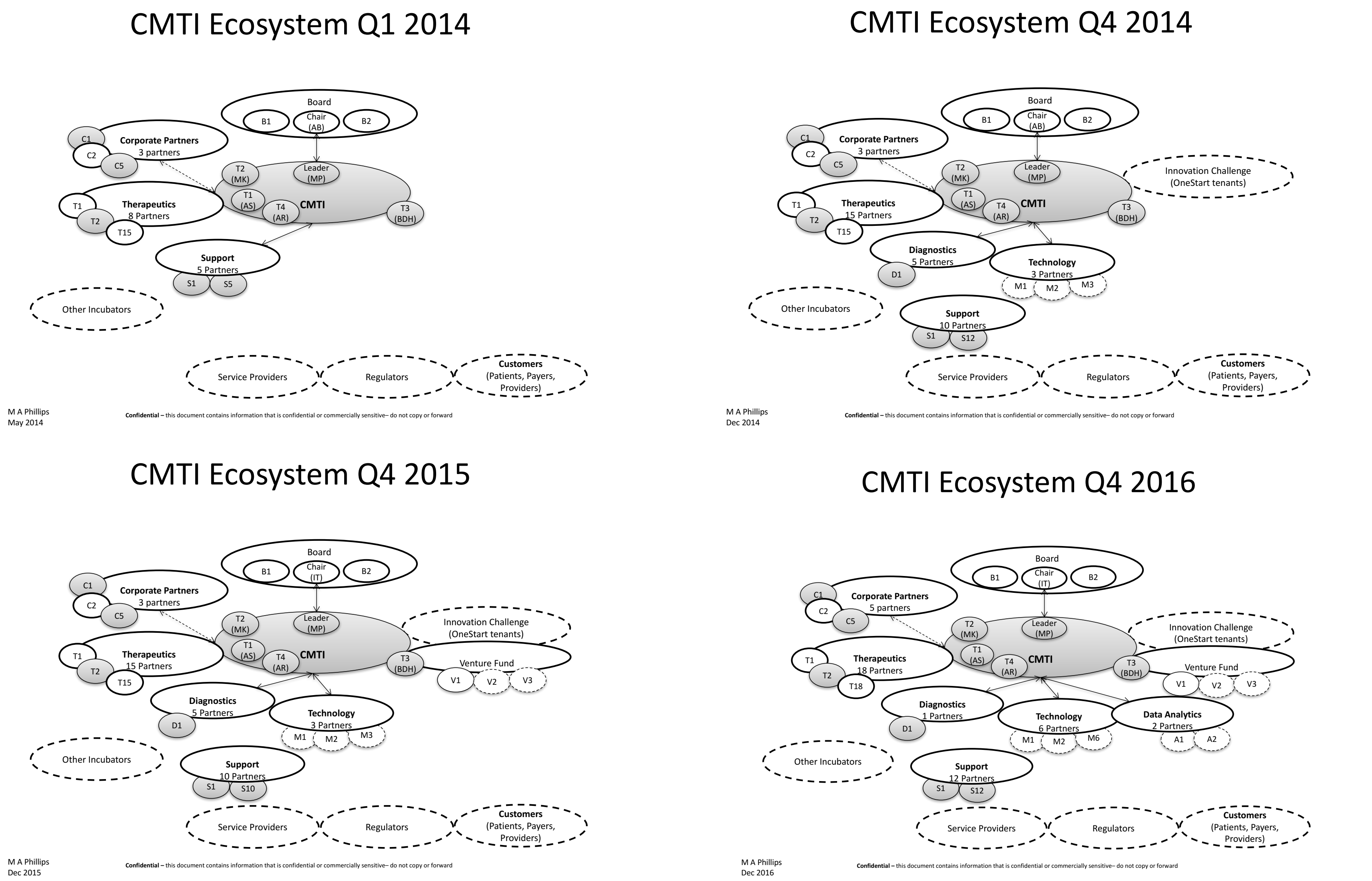

Figure 6-9 Case CMTI ecosystem evolution over case period

6.3.4 Findings

Ecosystem evolution

The evolution of the ecosystem, over approximately 24-month period, is shown in Figure 6-9. CMTIs ecosystem was already developed with biotech start-ups, pharmaceutical companies and academia. To support convergence required new interactions with technology companies. CMTI focussed developing a new network and partnerships. In addition to technology companies, they engaged funding bodies, charities and other investors: to attract funding for the facility and, to ensure convergent technology partners could secure future funding. From CMTI's perspective this was an important step; for the venture to succeed there needed to be confidence of 'deal flow'.

During much of the case CMTI were exploratory as they sought to identify the most appropriate solution and partners. There was divergence as they reached out to actors. As their strategy developed they focussed on diagnostics, technology and data analytics. They set up a venture fund and ran open innovation challenges to address known issues and attract new partners. They won a big for a new pilot manufacturing facility to complement their capabilities. This combination of partners and the emerging ecosystem enabled them to support developments in new 'convergent' areas, including: advanced diagnostics, precision medicine, regenerative medicine and bioelectronics. Ultimately, they decided on a strategy that was more evolutionary. The resulting, but still evolving, ecosystem is shown in Figure 6-10. The emphasis remains clearly on early innovation stages.

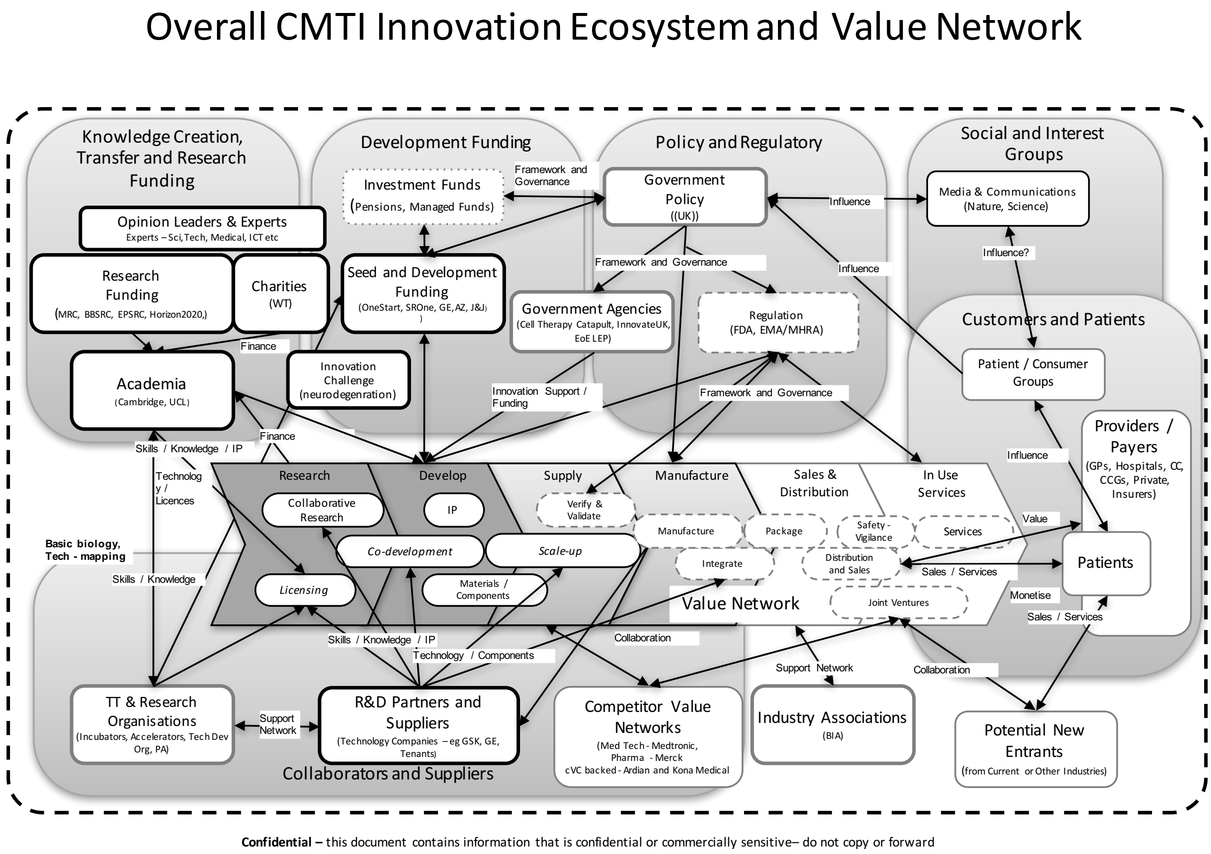

Figure 6-10 Case CMTI overall innovation ecosystem

Building external credibility and legitimacy

CMTI already had credibility in the UK biotech ecosystem. They moved to position themselves in 'convergence' through a series of interactions with diverse stakeholders. This was supplemented by online research via relevant public documents (see Figure 6-11). They also developed a database of potential collaborators and partners (see Figure 6-12) in relevant fields.

As well as developing their knowledge and network they held several 'summits' and workshops on 'convergence', increasing their visibility in the field. These did not always result in the desired outcomes and often required further engagement, as identified by CMTI3 after one workshop: *"'I think one of the things that has come out of today is the need to get that better clarity. So, we are going to probably do some more research. We are thinking of engaging even more widely. We will probably get someone in to do that."*

No	Activity	Type of activity	Key Words in search	Research	Link
65	Gizmodo	ARTICLE-REFERENCE	Bioelectronics	How Bioelectronics Promise A Future Cure For Cancer	http://gizmodo will-cure-cance
68	Springer	ARTICLE		The Convergence of Cochlear Implantation with Induced Pluripotent Stem Cell Therapy	http://link.spri %2Fs12015-01
70	BioIT	PRESENTATION		BIOELECTRONICS PRESENTATION OF RESEARCH CENTRE	http://www.lx. Bioelectronics.
87	Cancer Nano	ARTICLE			http://www.ca
102	ISG	ARTICLE ON CELL THERAPY CATAPULT			http://www.isp world-beating- centre
130	KQED	ARTICLE ON US PRECISION MEDICINE	Precision Medicine		http://ww2.kq 04/15/meet-th 3m-precision-r
134	OBR Green	article on precision medicine	Precision Medicine	New Clinical Trials Designed to Better Leverage Precision Medicine	http://obroncc e/New-Clinical Leverage-Preci
139	Biomarker Commmons	ARTICLE ON PRECISION MEDICINE	Precision Medicine	Pharmatech Precision Medicine Research System (AccessPPM) Takes Aim at Lung Cancer	http://www.bi marker-news/p medicine-resea takes-aim-lung
140	Eric Bender	ARTICLE ON PRECISION MEDICINE	Precision Medicine		http://ericben medicine/
194	Dental town	Article	Stem Cell		http://www.de n/article.aspx?
196	Agilent Technologies	company press release	Stem Cell		http://www.ag om/presrel/20
198	Cell Press	Article	Stem Cell		http://www.ce

Convergence | Company | Institute | Academic | Literature | Research Council | Investors | Open Innovation | +

Figure 6-11 Case CMTI example of their background research spreadsheet

No	Convergence Activity	Type of activity	Key Words in search	Research	Link
1	Centre for digutal health innovatio, University of California	Centre of Excellence (COE)	Bioelectronics		http://centerfordigita
2	Alivecor	Company	Bioelectronics	Use your smartphone or tablet to instantly detect a serious heart condition in your ECG-products for patients	http://www.alivecor.
3	iHealth	Company	Bioelectronics	portfolio of products- manufacture and design	http://www.ihealthla
4	Ginger	Company	Big data analytics	BIG DATA, BETTER HEALTH : Smarter care starts with your smartphone-At Ginger.io, we use smartphones to improve mental health care. Our app uses sensor data collected through the phone and self-reported information to identify people who may need help.	https://ginger.io/
5	Healarium	Company	Bioelectronics	Transitioning to new patient care models with an interactive engagement platform Healarium is a member of the StartUp Health and GE Entrepreneurship Program	http://www.healariur
6	QMED	Company-Qualified Suppliers to the medical device industry	Bioelectronics	The Top Five Examples of Tech Convergence for Medical Devices-	http://www.qmed.co convergence-medical-
7	Highlands & Islands and Moray Digital Health Research (University of Aberdeen)	University	Bioelectronics	The project will co-design, and pilot, a digital initiative which will encourage Highlands, Islands and Moray men to adopt healthy lifestyle behaviours.	http://www.abdn.ac. moray.php
8	Warwick Institute of Digital Health care	University			http://www2.warwick
9	UK Gov Digital Health Initiative	University	Bioelectronics	The UK: your partner for digital health solutions	https://www.gov.uk/ for-digital-health-solu solutions#digital-heal
10	Aridhia	Company		Aridhia is a world-leading health informatics company developing technology and capability that supports the management of chronic diseases, precision medicine, and biomedical research through the use of biomedical informatics and analytics.	http://www.aridhia.c
11	School Of Medicine, University of Dundee	University	Bioelectronics	Dundee ranked 7th in Global Health	http://medicine.dund
12	NHS Tayside	NHS Initiative	Bioelectronics	Tayside Health Board was established in April 1974 and is responsible for commissioning health care services for the residents in the geographical local government areas of Angus, Dundee and Perth and Kinross	http://www.nhstaysic
13	TPP	Company	Bioelectronics	UK Based IT company	http://www.tpp-uk.c

Figure 6-12 Case CMTI example of their 'database' of ecosystem actors

These challenges were addressed by conducting further interviews and holding follow-up workshops with other stakeholders. They also engaged potential investors and key opinion leaders, positioning themselves as a home for 'Future Healthcare', as they branded convergent medical technologies. These steps can be considered as building a legitimacy or credibility in the emerging 'convergent medical technologies' field, which they then planned to use to build value creating relationships.

Value Network Development

As highlighted above, much of the search and exploratory activity was based upon networking and building relationships through meetings, conferences and workshops. The basis for working together was more than just a connection, there needed to be alignment and confidence that the outcome could result in investment and deal flow.

Their search and network building approach was exploratory and evolutionary, developing as their connections and relationships grew and as new information and needs arose. Much of this activity was conducted by a dedicated team consisting of a few CMTI leaders, insightful external experts and resources. This appeared to achieve two things – one to minimise the internal resource usage and disruption, and secondly to ensure they had diverse inputs.

Developing a business model and advantageous-position

Considerable time was spent developing a viable business plan and model, as described by CMTI8: "*What we are trying to do is understand where [CMTI] could add value. The current research is short term, as input to the … Board meeting. But what we want to do is provide the Board with some proposals for who to target as potential Supply Chain partners, Technology partners and Digital partners."* This was not a simple process, and required exploration to gain understanding, followed by a decision on where to focus, CMTI1: "*Probably a bigger concern is focus. Given the complexity and lack of understanding, it would be easy to step in and step into the wrong place. Equally you cannot cover it all. So, we will need to think about how we focus."*

Towards the end of the case period, CMTI had Board agreement and investment, as explained by CMTI1: *"To develop our thoughts, we have been bringing, as you know, experts, panels together, running workshops. As we are asking the Board for £50M … we need evidence, it's not just us saying this and we are not trying to create 'just another science park', we want to drive an Open Innovation agenda. Thankfully, our Board agree… I think the big trick, and we have [CMTI6's] enlightened vision to thank for this, was to position convergence as just an extension of Open Innovation."*

Management and Capability Development

CMTI already had a well-developed suite of processes to engage potential partners and stakeholders. They also had established support and governance processes. To progress their convergence program, the leadership and team in CMTI largely developed existing processes. But rather than use the wider organisation and established management team, they engaged a new smaller team consisting of CMTI leaders and outsiders to develop the proposition and capability. They did not appear to make major changes to their processes but adjusted them as needs arose. The main changes were in their approach to search and gaining insights from the emerging ecosystem.

Importantly, to gain Board acceptance they positioned the move into convergence as an extension of their existing capability, thereby reducing the perceived risk. CMTI therefore appear to have developed via relatively minor modifications to a suite of existing processes, to create a new capability.

6.4 Case 2 – NMD

6.4.1 History and Background

The innovation organisation is a new R&D unit (NMD) within a major pharmaceutical company. The company had historically focussed on the development of new treatments, but has been involved in the development of diagnostic products and digital services to support its main pharmaceutical business. The focus of NMD is to develop novel implantable medical devices to modulate chronic diseases in organs. The innovations are convergent, involving bioscience, novel materials, electronics and digital (e.g., BNI), requiring an understanding of clinical mechanisms, miniature opto-electronic devices and digital systems to interpret signals and control the devices.

The NMD innovation was conceived in an internal 'White Paper' in late 2011 and formally reviewed as a business proposition by the Corporate Executive Team in 2012. The first employee, and head of the new NMD group started in November 2012, with one senior scientist joining at the same time. The first searches of journals, conference proceedings and meetings took place in early 2013 to identify potential research collaborators and the areas for focus. The team was slowly expanded in 2013, to five. By late 2013, 15 collaborative R&D projects were in place with academic researchers. In 2013, the firm also organized a conference to enable researchers to connect and map out the key challenges. In 2014, further senior team members were recruited and a corporate venture arm was created (to support investment in attractive start-ups in relevant fields). All team members recruited were experienced in R&D in the incumbent firm or had specific technical or domain expertise. While investments remained small, funding decisions were made via an *ad hoc* governance process signed off by a senior 'sponsoring' executive, but by mid 2015, the increasing investments and team size resulted in a new Investment Board being formed with senior executives and external experts as board members. By late 2015 the team had grown to 15, with over 30 collaborative projects and 3 start-ups invested. In 2016, the team size had grown to 35, with 35 collaborative projects, investments in 6 start-ups, and at the end of the case study period a major Joint Venture with a global technology company was completed, confirming the ongoing success and intent to progress the disruptive innovation. A summary timeline of the case history is provided in Table 6-6.

Table 6-6 Case NMD study key events

Sep 2011	Initial internal White Paper recommending the venture. Internal positioning.
Sep 2012	Formal agreement at Corp Exec Team to progress venture.
Nov 2012	Team Leader (NMD1) starts in role. 1st recruit (NMD4) in role to manage pre-clinical R&D activities
Jan-Mar 2013	Screening potential collaborators, academics and journal reviews
Apr 2013	Nature article – engaging wider scientific community.
Jun 2013	NMD commits to fund 20 academic projects (exploratory grants).
Aug 2013	Via Corporate Venture arm, venture fund ($50M) and Open Innovation Challenge (OIC) created to respond to perceived 'gaps' in ecosystem.
Oct 2013	Early R&D projects with academia – funded by firm, ca $200-250k per project.
Dec 2013	First of 15 collaborative R&D projects announced
Dec 2013	Firm Hosted International Conference - 150 researchers present, used to define the wider 'ecosystem' challenge and technology gaps.
Dec 2013	Open Innovation Challenge (OIC) defined
Feb 2014	New Scientist publication – aimed at further engaging ecosystem
Jun 2014	Nature Review publication - aimed at further engaging ecosystem
Jun 2014	Expanded team, NMD2 joins to address delays in OIC progress and manage funding relationships
Aug 2014	Reviewed OIC approach. New White Paper written for internal engagement
Oct 2014	NMD5 joins from Cambridge Uni. to work on neural interfaces
Dec 2014	32 collaborative R&D projects now in place. OIC increased fund (from £1M to £5M) and revised process – ten selected firms for phase 1.
Jan 2015	Memo to CET to obtain support for developing proposals and full business plan
Jan-Mar 2015	OIC - 25 applicants, 10 selected for phase 1 projects, contracts drafted and in place. Agreed phased expansion of internal team
Mar 2015	42 collaborative R&D projects in place (25 biology and 17 technology)
May 2015	OIC–review meeting with the 10 projects and potential technology partners.
Jun 2015	Formal CET review of strategy, approach and support
Jul 2015	New Investment Board in place, agreed program and support funding proposals
Jul 2015	Revised Business Plan and Budget plans (2015-2017)
Aug 2015	OIC Phase 1 readout from 10 teams and 16 potential technology partners attended, and selected 3 Phase 2 teams and tech partners to deliver chronic implantable platforms.
Sep 2015	Number of R&D projects reduced, ca 30 running.
Oct 2015	Start engagement of UK funding bodies and charities, aim to extend to EU in near future
Nov 2015	Venture Fund- 3 start-ups funded. Discussions to increase number of invested companies.
Q1 2016	Engaged Asian funders. In discussions to set up major JV.
Aug 2016	Announce JV with major Tech company (to complete 1 Dec 2016) 30 in internal team. 50 collaborators. OIC 5 teams (3 funded, 2 self-funded). Funding in US, EU, in development in Asia. 5 start-ups VC funded.
Dec 2016	JV finalised and in place. NMD1 appointed President of new JV.
Q2 2017	Target for first clinical study to start

6.4.2 Case Evidence

The research followed the methodology defined in Section 4. During the case study data was collected from interviews, observations and, public and company documents (obtained under a confidentiality agreement). A summary of the interviewees, observations and documents accessed is provided in Table 6-7. The interviewee sources are included in Appendix A4.

Table 6-7 Case NMD study data sources

Data Sources	Details	Aspects studied
Case Interviews	16 interviews: 12 interviews of 8 senior NMD leaders over the case period, and 4 interviews with 3 senior leaders with external collaborators. Totalling over 18 hours (ranging from 45 mins to 120 mins).	Identification of patterns in capability change; manifestations of skilful agency and existing innovation capabilities
Internal strategic documents	R&D Investment Strategy documents, NMD White Paper, NMD Manifesto and Business Plan, Project Update Reports and Investment Board review papers.	Identification of patterns in broader capability change; and existing innovation performance
Observations	Project Investment Board Meetings (1)	Articulation of new R&D expectations, leadership challenges and new investment strategy and structures
Company Public Documents and website	Annual Reports, R&D Pipeline Reports between 2013 and 2016. Open Innovation and News Releases, from 2013 to 2016.	Company trends and performance data. Public information on the new venture
Business Press and Industry documents	18 Public News Items, company press releases, public reports (e.g. NIH) and papers related to the venture (published in journals including Nature, etc.)	Dynamics of proposed technological innovation and engagement with external stakeholders

6.4.3 Analysis

Coding followed the process described in Section 4. Initial coding was based upon the exploratory framework. The main events identified in the exploratory framework under factors F1 to F12 were summarised and then subject to the ECPO analysis to identify plausible mechanisms. The ECPO analysis for this case is included in Appendix A5. During the case, simple ecosystem maps were developed based upon interview evidence (Figure 6-13). A basic roadmap was also developed to understand timelines (Figure 6-14). Further coding was developed from patterns of observations and potential causal mechanisms. In conducting the analyses, potential responses to the research sub-questions were considered.

6.4.4 Findings

Ecosystem Evolution

The evidence shows NMD growing their ecosystem significantly from a few players (e.g., three researchers), identified from a systematic search, to a complex network of over 50 academic collaborators, 'tens' of alliances with start-ups and technology companies, and a major joint venture. Additionally, strong links were built with funding bodies and investors to help create a viable ecosystem. At the end of the case period links were also being developed to regulators. The only actors not substantially engaged were end customers and patients, but the case firm indicated that this was by design, until they had god clinical evidence. The resulting, but still evolving, ecosystem is depicted in Figure 6-15.

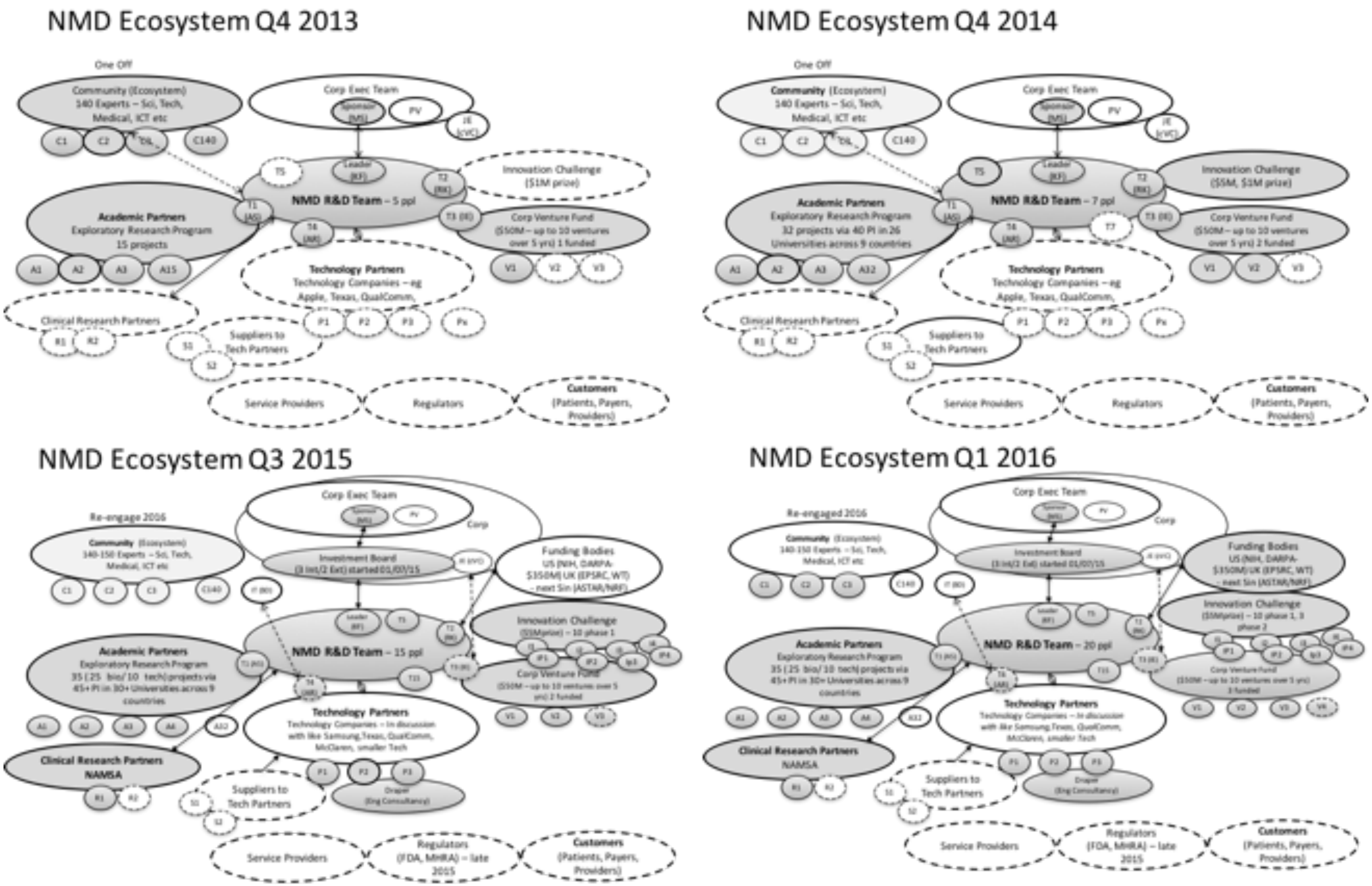

Figure 6-13 Case NMD ecosystem evolution during case period

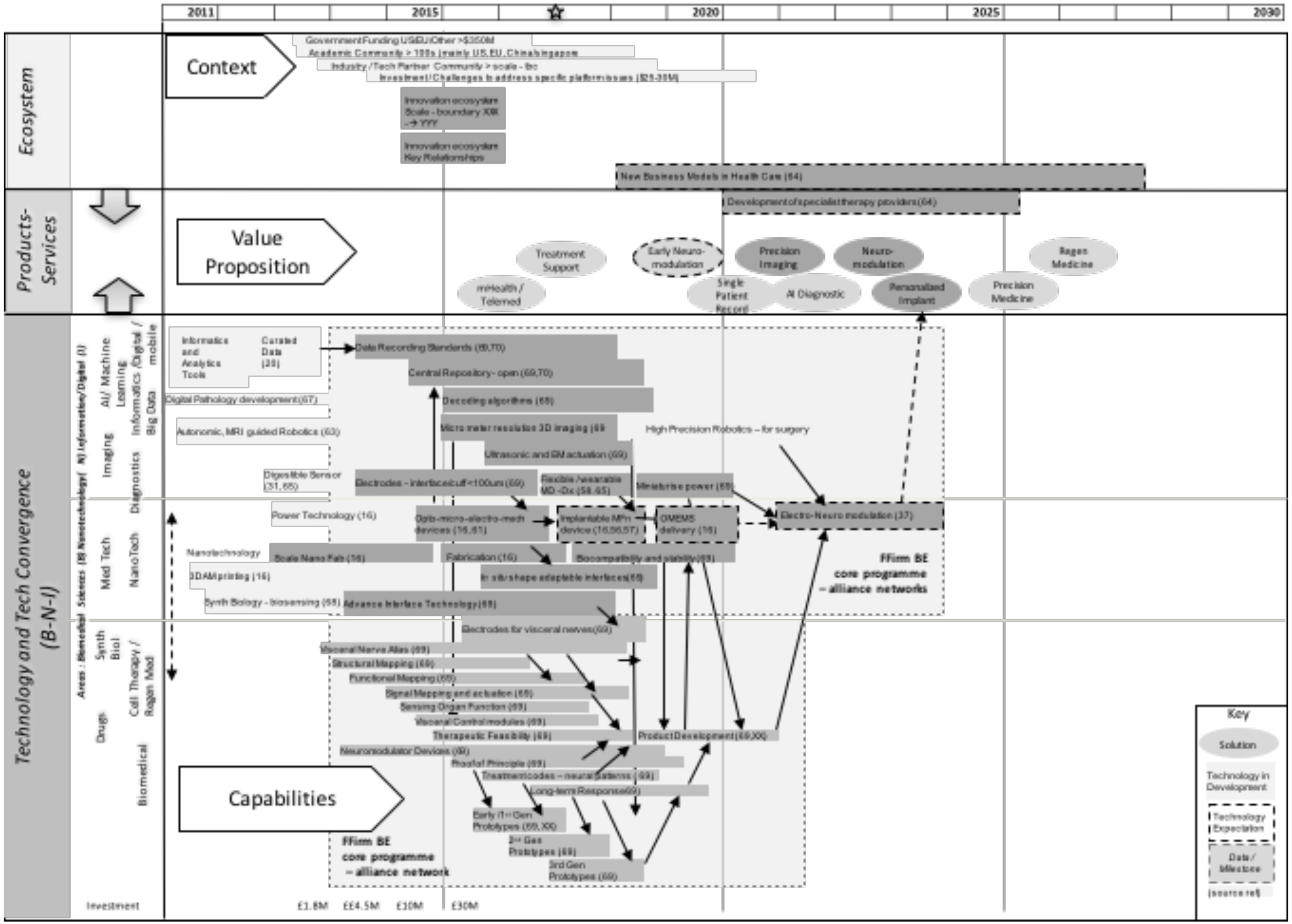

Figure 6-14 Case NMD ecosystem roadmap (trends) developed from case evidence

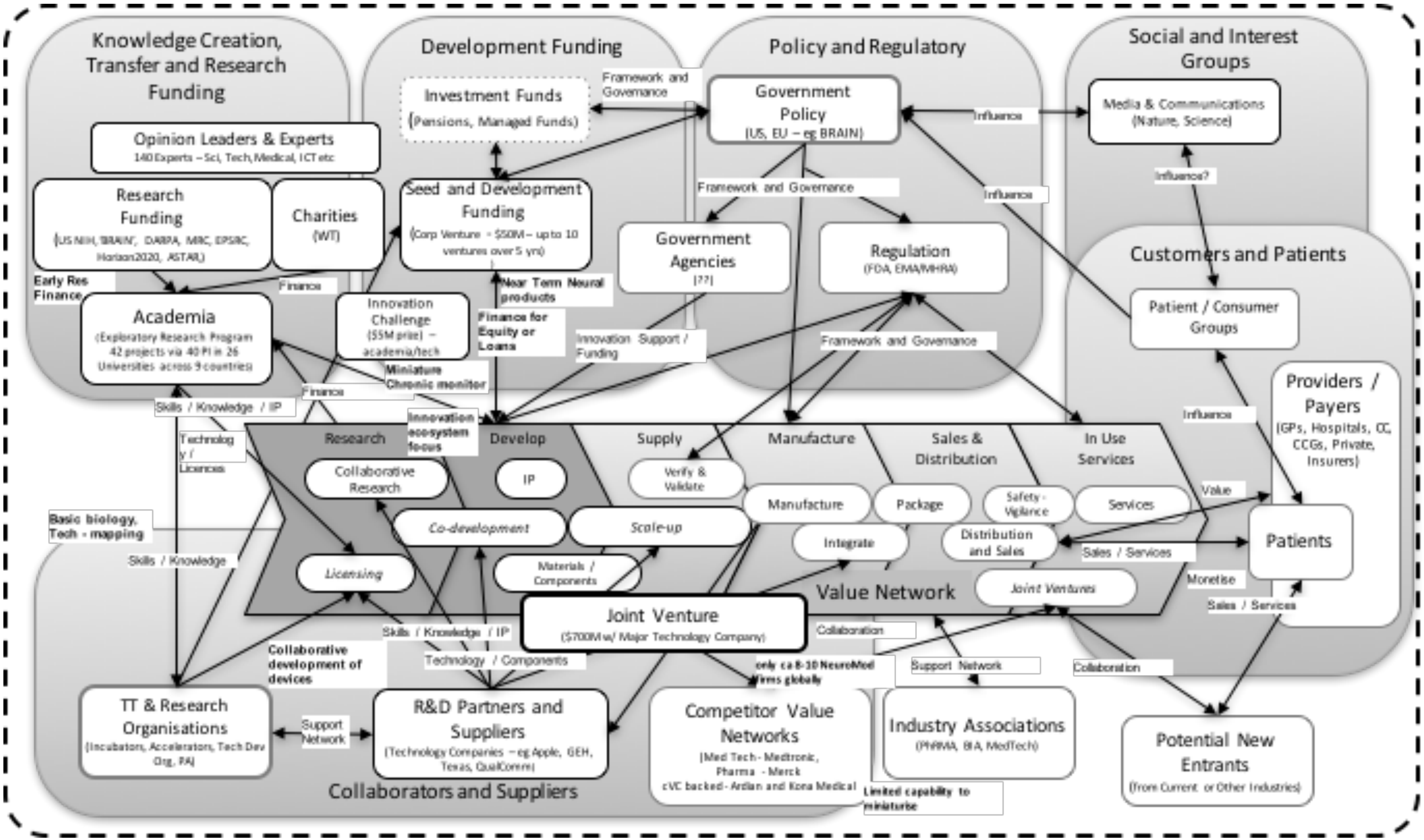

Figure 6-15 Case NMD overall ecosystem identifying key actor types and relationships

Initial search and exploration

The NMD group needed to develop searches for distant technological domains and to establish new partnerships. The head of the group (NMD1) explained: *"The path dependency does not really exist. There have been neuro prosthetics since 1962 with bladder implants and there have been pacemakers since the 1950s, but this needs a different approach. We don't know the fundamental details yet, we are still exploring that space, in terms of the biology and technology".* Also, the initial systematic searches, using existing capabilities, were not wholly successful, requiring adoption of modified approaches: *"We also tried to use classic approaches, so we put a problem out and asked for input, proposals …but that gave us a very low hit rate. Probably only one in 50 responses turned into something. The rest ended up cold. So, it only added a little to our network".* Similarly, existing open innovation processes were also tried but these were also modified (by funding the competitors and increasing funds) to ensure engagement and success (NMD4): "*… the way the program had been designed it assumed people could participate with their own funding. Which was a mistake. But after about 6 months and engagement with the community it became clear we needed to fund internally".*

Building external credibility and legitimacy

The ecosystem was nascent, with limited institutional support (in terms of government funding, venture funds, and support organisations). To overcome this the NMD group engaged with academics to develop a position paper (in Nature), helping to identify and legitimize the domain. Using this as a platform, to highlight the importance of the field, government funding was attracted to support academic research. This funding was supplemented by company R&D funds for projects not suitable for government funding.

As well as positioning the field, there was a need to establish their own role within it: *"[potential collaborators] concerned…whether our IP position was genuine. If you recall, we said that everyone would retain their IP. And there was a lot of scepticism about whether we were genuine about that" [*NMD2]. The nascent ecosystem was further supported by providing opportunities for researchers to engage and network, and then positioning their activities in more mainstream channels: *"On average every year we have had our network meetings where we bring all our funded PIs together. And we've had on average two meetings per year. In addition to that what has changed, this year, is that because we have now been funding research for the last 3 years we have now started to publically disclose the outcomes and output from all that funded work, through a number of channels".* [NMD2]. Investment funding was also provided to start-ups in the form of a corporate venture fund, modelled on a similar fund the firm operated in mainstream biotechnology. To support researchers and start-ups a specialist research organisation was contracted to provide development support services, mirroring an internal capability used to support biotech partners.

Building cross-industry alliances was not simple, the lack of domain knowledge and perceived risks act as barriers to engagement: *"A surprising challenge was that the Tech companies were actually quite risk averse. They are doing something completely new. They all see potential in health applications, but are not sure how to play or where to engage. They worry about things like scale, …, and liability. But having someone like us on board is helping. We know the space and are seen as someone who's hand they can hold." [*NMD2]

Creating Positional Advantage

The early strategic intent was to establish a sufficiently leading position to assess the potential of the new field: "*During the first two years our objective will be to enter and gain a leadership position in a way that establishes the magnitude of the long-term product opportunity"* – [Initial Business Case Paper NMD]. As the field's legitimacy was established their role moved to that of 'advantage seeking': *"We partner with experts wherever they are and drive much of our research through partnerships. We integrate a global network; it allows us to set direction and be the natural owner of future products"* – [Internal Business Plan – NMD].

This was achieved in several ways. Their increasing role within the ecosystem created positional power, with access to key research partners and institutions. The corporate venture funding provided opportunities to invest and appropriate value from related ventures. The open innovation program reinforced their central role, providing funds to address a key gap in the technology platform. Although the IP generated was made freely available to academic researchers, the incumbent firm established a position to commercially exploit it.

Building Value Networks

By building a network of academic partnerships they were able to position themselves to leverage future research funding (NMD1): "…*what's turning into reality is that we are the downstream partners. So, we can propose joint research with academics to apply for this funding. In company terms, we believe that these funding programs can not only feed new ideas or new disease opportunities in to our development pipeline. But it's also a way for us to get more leverage in the early research.'*

NMD also positioned themselves to be able take greater control of the IP and future value: '*Typically, we used 1-2 year partnerships, whilst we were exploring and knew there would be attrition in terms of science and partners. That was part of our model. Much of the value we've* *created has come from partnerships we've created with academics. The real balancing act this year has been to leverage the IP we've jointly created and use this as basis for [JV]. The deal is really conditioned on being able to bring this IP. [JV partner] tends to work with IP on outside, but we have or want on the inside.'*

They built partnerships in an exploratory way, making bigger commitments as knowledge, confidence and trust increased*: "For academic [partnerships] it was exploratory, there were many, so we expected that. We tried several to see what floats and then built with a few. As you know, the ones we started with were not the ones we have today. We had not expected that for the big partnership. But in fact, that's also how it played out. So, we had to learn and change."* By forming a joint venture with a global technology company, the first in this field, they generated a significant capability to explore and exploit innovations, by being able to accelerate progress: "*So, the driver was - how to we rapidly access the technology and engineering capability to build a game changing device".*

But information is selectively revealed, to build a stronger position to give them strategic advantage as an early mover (NMD1): "*But for later work, that's more commercial, we are more opaque. I'm happy for the competition …. To lull them into thinking or seeing this is just [NMD] and [partner] working on a 'moonshot', 10 years away... and not being hopeful about us being in clinic in the next 3 years. But equally there is no benefit to overhype it. So we want to make progress for the next year or so first".*

Building Internal legitimacy and acceptance

Like most early innovations there was a need to focus on de-risking and gaining credibility (by delivering small but consistent patterns of success): "*We will take an emerging approach to our investment direction. To start, we will place a number of carefully chosen but small exploratory, milestone-based investments across a spectrum of […]. We will then gradually double down on areas and partners that show the best delivery and the greatest promise*." [Internal Business Plan NMD].

The venture was managed by a small team, composed of experienced internal leaders, supplemented by external technical expertise. Like many potentially disruptive internal venture, there was a strong senior sponsor and to a large degree the venture was 'firewalled' from the rest of the organisation until it had developed sufficient credibility. The governance structure was then modelled on existing internal investment boards.

Although existing capabilities were utilised as a basis, the group had to develop new approaches including: access to agile short-term internal funding, support investment decisions by engagement with ecosystem stakeholders to identify and validate requirements, new forms of partnerships, new open innovation projects and corporate venturing. All were initially modelled on existing structures. So, whilst there was a need for change, they were at the same time aware that support for their activities would be higher if these are perceived as resembling approaches elsewhere in the company. This 'familiarity' was explained by NMD1, as part of a strategy to ensure a degree of alignment, but still be able to do what was needed: *"We got early buy-in to the proposition, aligned to a wider R&D Strategy, but the actual buy-in was at [corporate team]. As it was very small (in terms of money) we managed to ring fence it outside Pharma R&D and kept it simple until we had good evidence, and partners, and confidence we could deliver the promise. Then, yes, we did formalize it more, we needed that to justify the increased amounts of resource and spend, and the scrutiny required. The structures looked similar or 'familiar' – like a […] and an Investment Board. So, we looked like we were on the same playing field as other R&D groups, and in practice we were, although clearly were making different decisions, and we used different criteria."*

Summary of capability development

The case firm already had many established process and capabilities for innovation in their field. Where existing capabilities (particularly technical) did not exist, they used external partners or recruited specific skills to address this. The NMD team remained relatively small for a long period. This was a deliberate decision to avoid being seen to use significant internal resources and more importantly as they knew they needed significant external input, as identified in the NMD Business Case proposal: "*This effort will be lead by a 'virtual' [NMD] team. … Credible, integrative leadership across a major network of academics, business leaders and funding bodies will be key. …The team will only expand further if/when the management of the network so requires*". By keeping the team small and focussed and working with external resources, they were able to minimise internal 'disruption' and develop in an agile way.

The NMD group engaged with many of these existing organisational routines, and indeed modified them to progress the potentially disruptive convergent innovation. Few existing processes were simply replicated; most underwent modest changes. No process appears to have been radically changed. The group therefore appear to have developed their innovation by using many but relatively minor modifications to a suite of existing organisational routines, thereby creating a new capability that complemented the external technological capabilities in their value network.

6.5 Case 3 – DH1

6.5.1 History and Background

The venture is a new entrepreneurial 'start-up' within the NHS in Northern England. The focus of the unit is to develop digital solutions (e.g., using mobile technologies) to improve patient care pathways, outcomes and experience, and to help improve NHS services. The innovations are convergent involving clinical and social care pathways, a range of technologies and digital solutions.

The venture started in January 2014, with a proposal by an entrepreneurial and passionate NHS manager to make better use of digital to improve services and outcomes. The aim was to harness digital technologies to improve NHS and care services and to enable patients and carers to be more empowered in the management of their condition. To progress this program several fundamental challenges needed to be addressed. Firstly, the proposed venture did not fit into any existing organisational structure, and in fact, spanned many organisations both within the NHS and in community care. The venture was also aiming to develop technologies which the incumbent organisations (local NHS Trusts) had little or no expertise in, not just in terms of technology, but also how to develop such a technology. It therefore required to work with a diverse range of technology providers and digital technology companies to provide solutions, most of whom were unknown at the outset of the venture.

The case research started during the first year of the venture's existence and followed the new unit for nearly two years (until December 2016), so provides evidence from close to its inception through a major milestones whereby significant investment and commitment was made, and the venture was put on a long term and sustainable footing.

A summary timeline, highlighting key events in the case history is provided in Table 6-8

6.5.2 Case Evidence

Case Research followed the methodology developed in Section 4. During the case study, data was collected from interviews, observations and, from public and company documents (obtained under a confidentiality agreement). A summary of the interviewees, observations and documents accessed is provided in Table 6-9 and the interviewees are summarised in Appendix A4.

Table 6-8 Case DH1 study key events

Date	Event
Jan 2014	Formed DH1 (1 secondment and 1 grad trainee), working from local NHS offices. Pilot Funding from several NHS Trusts and a CCG. Won SBRI Award with App developer.
Feb 2014	DH1 held first “Health Hack” day to engage patients, providers and developers
Mar 2014	Outlined ideas to innovate in NHS using digital / mobile (communicated via web and social media)
Apr 2014	DH1 held first Care Planning workshops
May 2014	DH1 provided first guidance for mobile Health developers
Oct 2014	DH1 hosted Mental Health and Chronic fatigue workshops. Portfolio of over 10 projects.
Nov 2014	Case interviews started
Nov 2014	Small DH1 team in place (3, plus part-timers). ‘Heart of Habitat’ sessions start creating opportunities to bring people together on a more regular basis. Co-authored Conference paper for International Journal of Integrated Care.
Jan 2015	Completed first year with over 15 projects ongoing. Held workshops to ‘catalyse’ additional projects.
Mar 2015	25 small, medium, large projects in progress. (Project list available) – mainly at ‘catalyse’ and early ‘incubation’ phase.
Jun 2015	Completed development of first App under SBRI grant for Chronic pain.
Jul 2015	Moved into new independent offices. Team now 5 people full/part-time. Engaged in Accelerated Access Review (NHS England), NHS Digital. ,
Sep 2015	First complete project delivered. Bespoke SMS application. Delay in handover, due to customer availability.
Oct 2015	Re-branded themselves broadening beyond ‘health’ to include community and care. Revised Stakeholder analysis to better map out key groups locally and nationally. Reviewed Business Model using Business Canvas (e.g., Osterwalder). As part of business planning ahead of proposed spin-out at end 2015 / early 2016.
Dec 2015	Targeted spin-out Board meeting.
Jan 2016	Board meeting did not take place. Have in-principle agreement to continue, have sufficient near term funding and continue to develop plans. Still reviewing business structure options. Recruited more staff to support growing workload. Winning new contacts, now with different and more diverse partners. Growing their network and ecosystem.
Mar 2016	DH1 provided input into NHS Framework (influencing at national level)
May 2016	Moved to new location, as team grew (now 6 full-time, plus part-timers and contracts) and funding more secure. Procurement Framework in place, giving greater flexibility to operate with developers. Final business structure still being developed. Deposited first Code in GitHub. Working more widespread geographically (other regions). Providing solutions on both mobile and web. Expanding ecosystem, e.g. Barcelona. DH1 see role as a change in focus from helping connect to delivering solutions. Engaged to provide solutions for NHS England. Business plan in place.
Aug 2016	Co-design “Our GP’ for NHS Scotland to provide new digital services
Sep 2016	Continue to engage others, with more diversity including academic papers, medical journals, community. Continuing to build ecosystem. Have secure funding for next 18-24months.
Dec 2016	Expanded facilities. New contracts with other Trusts. Considering creating space for co-locating start-ups.

Table 6-9 Case DH1 study data sources

Data Sources	Details	Aspects studied
Case Interviews	15 interviews of 6 senior managers and business leaders over the case period, totalling over 15 hours (ranging from 30 mins to 90 mins).	Identification of patterns in capability change; manifestations of skilful agency and existing innovation capabilities
Internal strategic documents	7 Business Plans, internal Board and governance reports, and project status reports	Identification of patterns in broader capability change; and engagement with ecosystem
Observations	6 Workshops, project meetings, and internal team meetings	Observation of innovation practices and working with partners
Company Public Documents	5 reports and general communications	Company communication to various fora
Company Website	News updates, thought-pieces and open calls for input from 2014 to 2016.	Public information on the new ventures and engagement
Academic, Business Press and Industry documents	21 Public documents including Reports and papers DH1 contributed too, other documents on initiatives related to ecosystem	Examples of engagement with others, and driving forces elsewhere in ecosystem

6.5.3 Analysis

Coding followed the process described in Section 4. Initial coding was based upon the exploratory framework. The main events identified in the exploratory framework under factors F1 to F12 were summarised and then subject to the ECPO analysis to identify plausible mechanisms. The ECPO analysis for this case is included in Appendix A5.

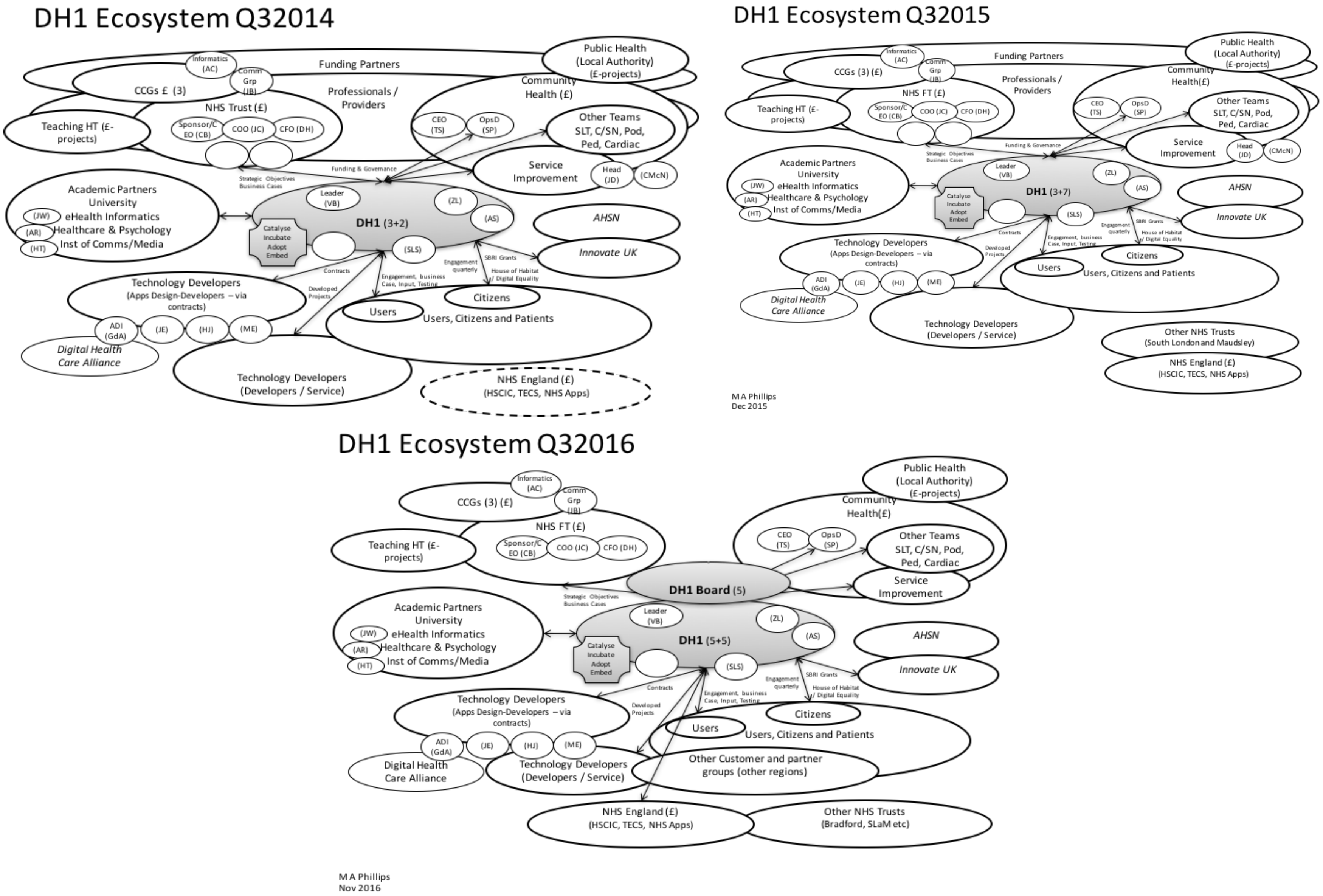

Figure 6-16 Case DH1 ecosystem evolution during case period

6.5.4 Findings

Ecosystem evolution

The evolution of the ecosystem over approximately 24-month period is shown in Figure 6-16. From the start of the case DH1's ecosystem was already partially developed with several NHS Trusts, CCGs, patient groups and developers engaged in activities. The initial focus were the users: the patients, carers and providers. The evidence suggests that DH1 was also focussed developing many new partnerships over the life of the venture. Whilst the initial focus was local, they actively engaged more diverse actors and spread their geographic and policy reach (i.e., active exploration and evolution).

The other main change to the ecosystem was around governance and funding. Initially DH1 reported to many Trusts and a CCG, as their funders. This resulted in some bureaucracy and inefficiency for issues involving cross-funder decisions. Change to this governance 'system' was slow, with several solutions proposed and reviewed and re-reviewed. Ultimately, they moved to a simpler, smaller structure with a new Board that provided the diverse input and agility required. The resulting, but still evolving, ecosystem is shown in Figure 6-17.

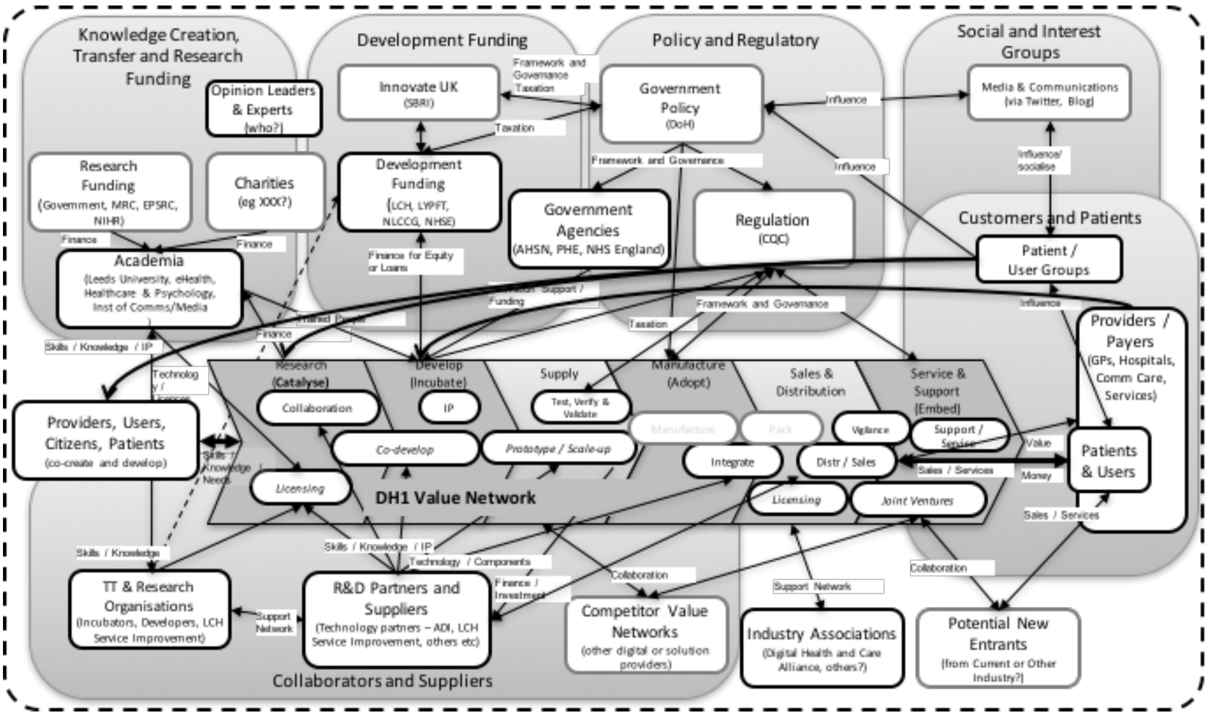

Figure 6-17 Case DH1 overall innovation ecosystem showing key actor types and relationships

Building external credibility and legitimacy

DH1 developed several innovations, in partnerships with users, funding bodies and developers. Each product met a specific need, but they were also engaged in creating a broader capability, essentially a 'platform', where products and code from different solutions could be used as a building block for future innovations. Most solutions were purely digital but disrupted existing clinical and care pathways.

The new DH1 group was small, flexible and highly empowered. The CEO, being an NHS employee, was trusted by local providers. From the outset, they were deeply engaged with the local ecosystem, using a combination of meetings, workshops (see Figure 6-18) and social media tools to network with patients, providers and others.

A key objective was to ensure that innovations met patients' needs, so they regularly engaged them, as further explained (DH1-1): *"Another approach is that Conferences rarely engaged patients. We are therefore going to run a one day conference – that helps positioning – on people driven health and well-being … Run as an 'un-conference'. So, the input is all from personal experience, and participant led."*

Figure 6-18 Case DH1 observation at design event

Early on they mapped and identified key stakeholders in terms funders, customers' groups and patient groups. There is also evidence of engaging in the ecosystem more widely (i.e. with other tech start-ups or network organisations like DHACA and within the wider NHS).

They also recognised that just attending events was not enough to become credible and visible, DH1-1: *"It's also important that what we have done is visible, so people can see our track record.*

So, another important part of our role is to curate and make public. So, you will find searchable content on our website, in our blogs etc.". This approach was increasingly recognised by other stakeholders and Trust Board members (DH1-3), as valuable: *"... it provides focused, dedicated resource that is key and critical to service development. And also, the expertise of [DH1]: developing relationships, networks and contacts, ... They offer service driven solutions. They understand NHS, health and services. They provide - Drive, Resource, Energy."*

Having developed a position of credibility locally, they worked in the broader ecosystem and at national level, increasing their network and sphere of influence, as indicated (DH1-1): *"When presenting to work stream 1.2* [National level NHS work stream] *it was clear that there is a lot going on, on the supply side, and to incentivize industry to partake, but little to help build demand – in the NHS and services"*. For example: "*... as well as incentivized development, there are efforts to ensure standards, they are assessed by clinicians. So, there is a real move to stimulate the supply side on priorities. And reduce people delivering things that are not needed. But the demand side not so well developed*."

Value Network Development

As highlighted above, much of the search and exploratory activity was based upon networking and building relationships through meetings, conferences and workshops. They also used open calls where appropriate, via the internet: "*What we did in December was an open call, we were looking to incentivize interest. So we got several teams and questions. Many of the solutions people were looking for are website based (quite common) or something to do with workflow (which is IT related)."* The exchanges were also used to help develop their own value network, which was largely built through networking and relationship building: *"Our ecosystem is a lot bigger. It's mainly through networking. We attend and event or conference or we run an event for people. .... So the process is we might meet or find we meet several times at different events and make a connection. If there is some common ground and common culture, we might look to work together*."

The basis for working together was more than just a connection, there needed to be alignment of capabilities and culture, (DH1-1): *"I'd describe the common interest as something more, there needs to be 'congruence' a real alignment, not just in terms of the outcome, but also cultural and how you are going to do it. Connections do not just happen. You need to 'cultivate' to create the right opportunities. That is where I see this spirit of generosity and being open, learning together as being important."*

Their search and network building approach was therefore exploratory and evolutionary, developing as their connections and relationships developed and as new information and needs arose.

Developing a business model and advantageous-position

DH1 followed a 'classic' model of initially pitching to local enterprise boards, getting some seed funding and interest, and then using that to build upon their own network. They also used the Business Model Canvas (Osterwalder et al., 2010) to develop their initial business model (see Figure 6-19). However, this was later changed, as the one-off design did not fit emerging needs.

They initially created a local positional advantage, seen as 'people to go to' (DH1-5): *"I think they offer co-design and the mix of creative mind sets, design mind sets and clinical need. The brokering of different resources. We value [DH1]s world view and insights. And the network behind those insights."*. The combination of delivery and visibility, and increasing networking provided opportunities to engage more widely: *"We are well connected locally and continue to spend a lot of time networking. We are always making new connections. We are reasonably well known locally, so people come looking for us too. More broadly we are connected to NIB and some of their work streams; so that gives us an opportunity to influence at national level, particularly on Open Source software strategy…".*

Figure 6-19 Case DH1 example business model 'design' activity

As a result, they gained increasing influence at national level, DH1-1: *"I sit on two groups at a National work stream level. We are working on tech enabled commissioning - helping* *commissioners for technology. The digital context has moved on recently, with the recent announcement on mental health on-line platforms and NHS Choices".*

Towards the end of the case period, the group had grown modestly (still less than 10 people) and was actively looking to provide co-working space for digital health start-ups, to help foster their ecosystem, (DH1-1): "*One thing we are beginning to explore is creating our own ecosystem, environment for digital health start-ups. There is still little in the area, except for us, but we don't have space. We are looking to create some space with us, for start-ups and developers to work. That would help them and build our own ecosystem"*.

Management and Capability Development

The initial team was very small with only one secondment and an industrial placement student. The first secondee (and leader) was highly motivated and entrepreneurial, seeking to use digital technology to improve services and outcomes. She skilfully navigated the existing structures to obtain funding and sufficient endorsement to proceed without formal governance at the early stages. Many of the early team members had provider (NHS) experience but little start-up and innovation experience. So, the team had to learn by using existing processes working with others and from experiential learning, DH1-1 stating that they: "*Use existing on-line capabilities to see what works and doesn't work, then tailor a better solution*". Many of their early processes used co-creation approaches, so learning was rapid. They evolved their processes frequently, using feedback from events (DH1-1): "*Doing it the way we did in December spreads the team to thin, and we cannot engage to help develop the business cases. In future, we will be more focused*."

As workload and funding increased the team was grown organically. They evolved the project management and reporting tools used as they evolved, using Lean Start-up (Ries, 2011) practices. Major workloads, such as software development were outsourced to contractors. But they sought to be able to re-use work to improve efficiency (DH1-1): *"One of the first things we are doing though is understanding how to create code in GitHub repository for code. This will enable us to re-use and share code, making future develops simpler and cheaper. We are currently doing technical due diligence, to ensure can properly document and can re-use the code."*

Existing process, at times, were limiting, (DH1-2): "*At the moment the process is an NHS Procurement process, it is very laborious. We can readily get developers on to a list for Discovery Day input etc., but then the build stage is a lot more regimented. We cannot use a list of preferred suppliers and then select from one of them; it's not allowed by NHS Procurement. We have to go through a full procurement process, with lots of documentation."* requiring DH1 to seek ways to work around these and develop alternatives. As the scale increased more formal governance arrangements were put in place, but these were often unsatisfactory in terms of getting decisions made. Eventually a new 'board' was created that provided the agility and governance to meet DH1 and stakeholders needs, as described by the CEO: "*We have not gone with the model we discussed before. We have now decided that it makes sense to remain wholly within the NHS. At least for now. There was a lot of feedback that our position, in the NHS, was important to credibility and trust. We didn't want to undermine that. What we have continued to work on is creating a new Board, so that we can simplify our governance*."

In summary, DH1 started by using many existing processes, and modified them to progress their innovations. Few existing processes were simply replicated; most underwent some modest changes. No process appears to have been radically changed, except for the desire to streamline procurement processes. The group therefore appear to have developed using many, but relatively minor, modifications to a suite of existing processes, to create a new routines and develop their innovations.

6.6 Case 4 – MLD

6.6.1 History and Background

The venture is a 'start-up' developing a novel digital diagnostic product, using a machine learning algorithm to identify patient risk of cognitive impairment. The venture requires combining biomedical science, device and analytics, and has the potential to disrupt existing clinical pathways.

The venture started in April 2013 with two founders, both working part-time. During the case period, the MLD venture progressed from an exploratory study, to a multi-million dollar VC funded start-up, a value network of contractors and alliance partners (technology, quality and clinical), with the technology working on the preferred platform and user studies ongoing. Plans were in place for a formal clinical trials and regulatory submissions in the EU and USA.

The research followed the venture for over two years (until early 2017), so provides evidence from close to its inception through early development and a major milestones whereby significant investment and commitment was made.

A summary timeline, highlighting key events in the case history is provided in Table 6-10.

6.6.2 Case Evidence

Case Research followed the methodology developed in Section 4. During the case study, data was collected from interviews, observations and, from public and company documents (obtained under a confidentiality agreement). A summary of the sources (interviewees, observations and documents accessed) is provided in Table 6-11. Further information on the interviewees is provided in Appendix A4. Direct observation at meetings and workshops with innovators, investors and other key stakeholders also provided evidence of practices and capabilities. All data was securely stored on a confidential cloud server and uploaded into NVivo CADQAS software for analysis.

Table 6-10 Case MLD study key events

Date	Event
Apr 2013	MLD1 formed company based upon research conducted by MLD2 in neurosciences and computing
Jun 2013	Raised £Xk via a CE competition, using this they filed a patent and conducted the pilot study/preliminary trial – ca 40 individuals healthy and with disease
Dec 2013 to Feb 14	Develop prototype test on PC and conduct Pilot study. Complete pilot study and conduct analyses. Evidence is positive.
Feb 2014	Develop Web Application version built and tested –enabled access to wider 'test' groups
Q2 2014	Continued to enter competitions and build business case and IP position. Won small awards - CE and with IUK to fund some web based development.
Oct 2014	Had TSB bid with Cambridge Uni in pipeline but lead investigator pulled out due to workload, so bid failed.
Dec 2014	Entered OneStart competition. Selected as semi-finalist. Held meetings with investors / VCs (observed)
Jan 2015	Discuss options with entrepreneurs, VCs and potential team members. Decide some current 'associates' are not focussed or contributing. Revise team. Bring new Chairman (MLD3) on Board. Continue to pitch to events and VCs. Major review of business plan
Mar 2015	Now have business plan in place. Continue to engage potential investors and alliance partners in clinical research etc.) as they build their ecosystem and business case.
Mar 2015	Engage potential investor (MLD4) in discussions.
Apr 2015	Meet [major Tech company] for potential alliance (observed). Did not make OneStart final. Started more systematic review of ecosystem and value proposition, to better articulate benefits and potential partners. Engaged NIHR DEC– potential joint project to do market research
May 2015	Still in discussions with MLD4 investment fund, potential interest in investment and on philanthropic grounds. Appoint new Medical Director from EL NHST
Jul 2015	Investment from MLD4 not forthcoming. Terminate Chairman over poor performance.
Nov 2015	Meet EL NHS Trust to discuss options for clinical study
Dec 2015	Complete LOI and agreement for VC funding of ca $1.25M
Q1 2016	Conduct exploratory larger trial to demonstrate algorithm works on simple device (Raspberry Pi).
Mar 2016	Review regulatory options, following discovery of new FDA approved product (using similar approach). Determine there is still an opportunity, but want more in-depth market research on competition.
Apr 2016	Review options for platform. Conduct some further market research with potential users. Mobile is preferred. Focus on iPad as initial offering.
May 2016	Medical Director moves to another NHS Trust. Begin discussions to engage them and memory clinics and local GPs. Ongoing process of customer input
Jun 2016	Engage consultant to undertake market research on competitors. Conclude MLD is still well positioned as features and value proposition is different / better. Start discussions with ON (IT and gaming company) to build early prototypes for tablets / iPad application
Sep 2016	Develop new website and marketing materials. In discussion with User Needs / User Experience consultants (BA) to help in UI design
Oct 2016	visit Canadian brokers to progress potential IPO. Increasing funding to around $4M. Delays in payments by VC backers. Have iOS / iPad version developed.
Dec 2016	engage Regulatory consultant and quality person to help put regulatory strategy and quality management system in place. Start UI studies in USA using iPad version.
Jan 2017	Bridge funding obtained for IPO. Met Accenture for potential alliance. Re-engage [major Tech company]. New discussions with UK KOL – agree to support project and trials. Recruit employees for software development and project management

Table 6-11 Case MLD study data sources

Data Sources	Details	Aspects studied
Case Interviews	15 interviews of 4 senior managers and business leaders, totalling over 15 hours (ranging from 30 mins to 90 mins).	Identification of patterns in capability change; manifestations of skilful agency and existing innovation capabilities
Internal strategic documents	21 documents including Business Plans, internal reports, project status reports, grant applications and emails	Identification of patterns in broader capability change; and engagement with ecosystem
Observations	15 Meetings, presentation and Workshops, and internal team meetings	Observation of innovation practices and working with partners
Company Website	Company information 2016	Public information
Academic, Business Press and Industry documents	2 Public documents	Driving forces elsewhere in ecosystem

6.6.3 Analysis

Coding followed the process described in Section 4. Initial coding was based upon the exploratory framework. The main events identified in the exploratory framework under factors F1 to F12 were summarised and then subject to the ECPO analysis to identify plausible mechanisms. The ECPO analysis for this case is included in Appendix A5.

6.6.4 Findings

Ecosystem evolution

The evolution of the ecosystem, over approximately 21-month period, is shown in Figure 6-20. As a start-up, MLD have virtually no ecosystem to start with, so required new interactions with technology companies, funding bodies, and others. During the early case MLD were exploratory as they tried to identify the most appropriate partners. They built from a core of NHS contacts to network with key opinion leaders. Via their slowly growing network, they attracted external investment from a VC, and potential IPO.

The value network consists of a range of contractors, consultants and technology companies. The resulting, but still evolving, ecosystem is shown in Figure 6-21.

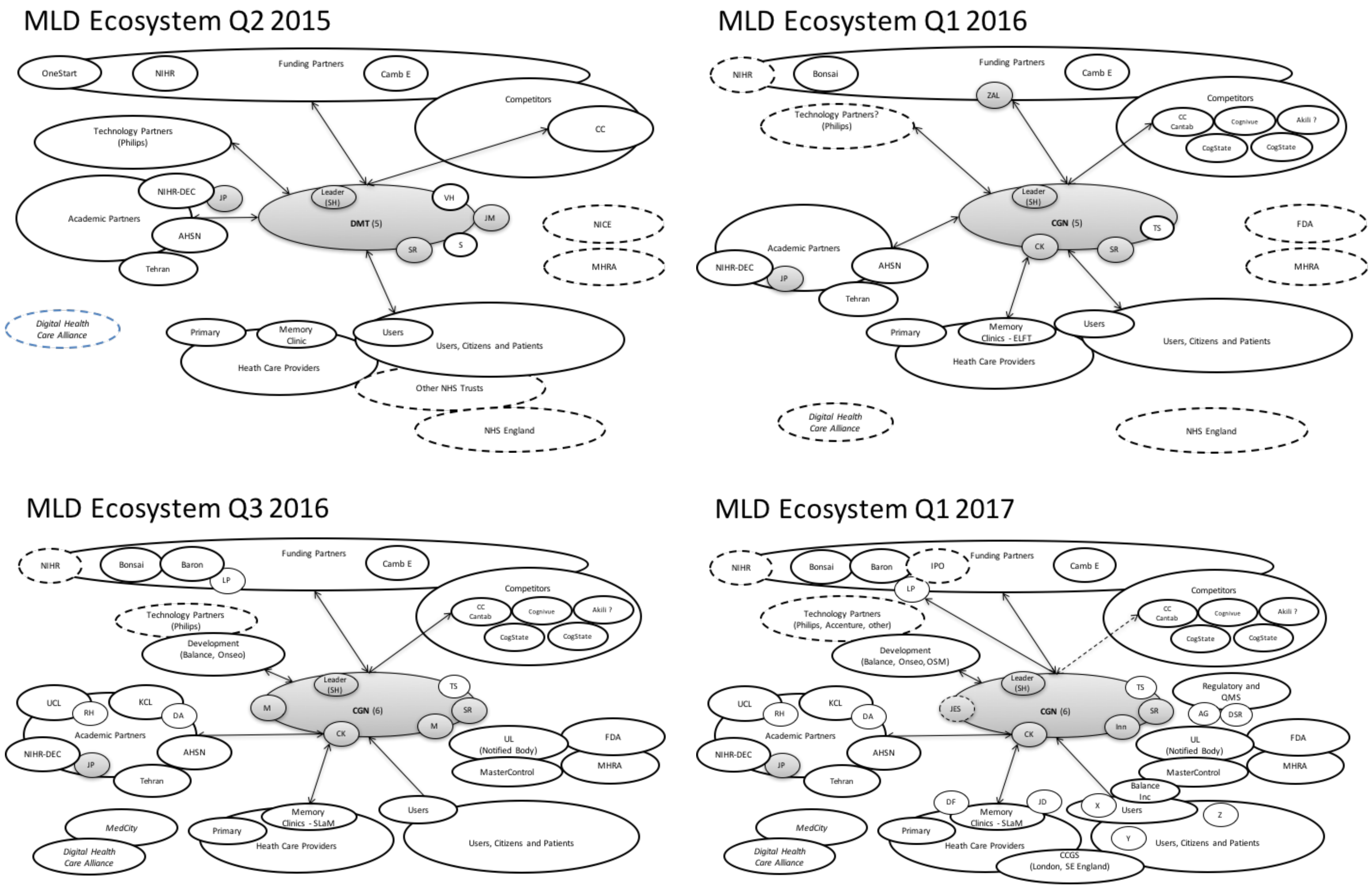

Figure 6-20 Case MLD ecosystem evolution during case period

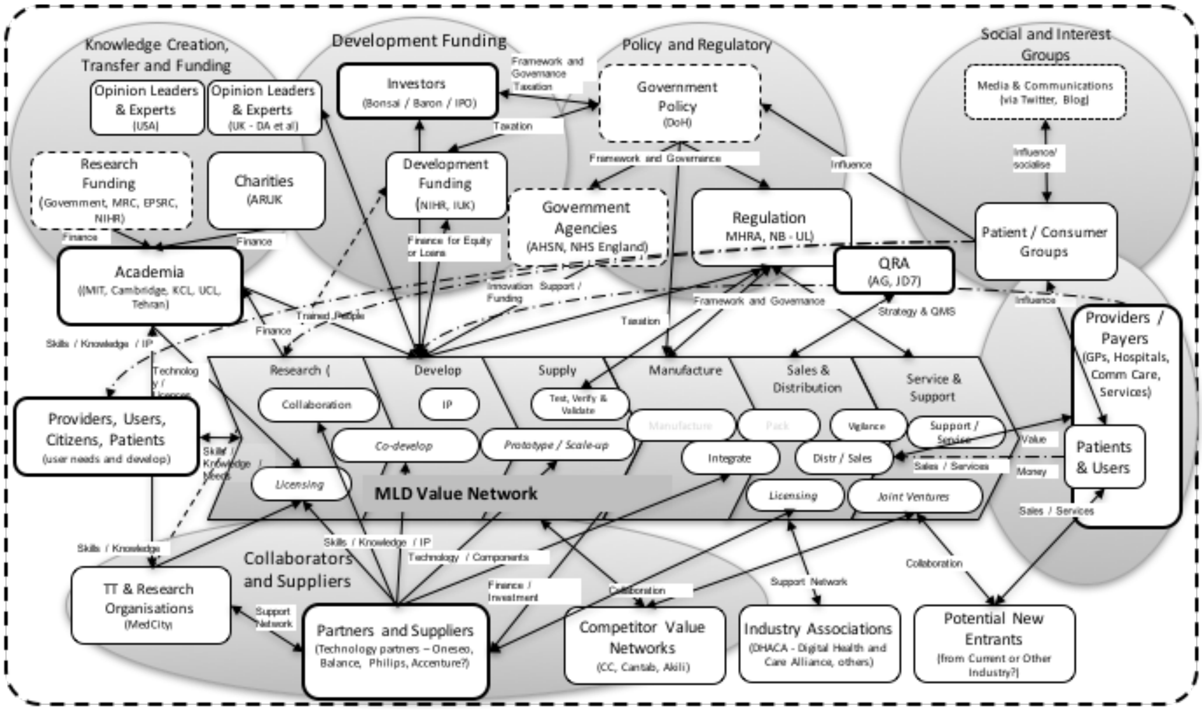

Figure 6-21 Case MLD overall innovation ecosystem

Managing relations in ecosystem

Identifying the insightful and useful actors in the ecosystem was slow at first, and relied on introductions, as described (MLD1): *"So we sent a cold call email out to the likely stakeholders. We probably only got a couple back. But we had a discussion with them and they introduced us to others."*. Building their network continued to prove difficult and slow, explained by the CEO as: *"To be honest, it's a bit like Brownian motion. You are forever moving around, bumping into different people. And you cannot predict beforehand whether they will add value or not, or even immediately after. Also, its something about when you do business and have the meeting. So, it's not pre-determined, it seems completely random. You might expect them to be interested based on your prior knowledge, but it's not always like that, and it might just be timing or it doesn't fit their exact interest".*

Access to the medical community was particularly difficult as competitor firms had already established links with many clinicians, but following a connection with one, the network was expanded, (MLD1): *"... he provides credible expertise, especially to medical community. And can access NHS network to help progress trials but has little experience in this area, so will be learning and of value to him".*

The challenges of developing an ecosystem were summarised by the CEO as: *"So, you have to invest in relationships, and it consumes your resources. But back to our network, we are building it, we have the first few critical ones in place and then we are working through them, to see more".*

Building external legitimacy and credibility

As well as building their ecosystem, there was a need to be "seen as" credible to investors and potential partners. Early feedback indicated that the new technology was not well understood, explained by MLD1: "*Feedback from bids was that we need to make 'more inventive' or its not properly understood. … Can we describe what is new or challenging about it?".*

As the venture developed, the innovation gained credibility, largely by addressing the feedback and improving their messaging such that they were seen as offering potential in the eyes of investors (MLD4): "*I think the technology is novel. I've had my own people do some basic due diligence, so I am aware of … and others, but this appears different. If it works, it offers a different approach, and importantly an earlier diagnosis."*

This credibility being achieved through a combination of engaging diverse audiences, delivering specific outputs and evidence, and by careful (re-)positioning.

Value Network Development

As highlighted above, much of the early ecosystem activity was based upon networking and building relationships through meetings. Their search and network building approach was exploratory and evolutionary, developing as their connections and relationships grew but was not always successful and often needed multiple interactions, (MLD1)*: "We find people, we might make a little progress. But they don't all work out. We are continually exploring new possibilities, in terms of partners, investors and people we could work with for trials etc. I think one of the challenges here is unless you have the finance in place and can buy services, you need to have several options in play, because one might not come off, and you don't have any leverage. So, they can just walk away. So, building the network is critical."*

By steadily building relationships and credibility, they developed a viable value network of clinical partners, specialist contractors, technology companies and investors.

Developing a business model and advantageous-position

Considerable time was spent developing a viable business plan and model. The process was iterative and evolved as they engaged with potential customers, investors and other opinion leaders. An example of an exchange that changed their perception was explained *(MLD1*), thus: *"When we first started we though that pharma might be sweet spot, as the test would support prescriptions. But after talking to J&J and Roche we realised we were not aligned. Their focus is on biomarkers that specifically link to their drugs"*

Following such feedback, they decided to formally map the key customers, by type and assess what would create value for each of them and how to deliver it. This value analysis helped in defining several potential products, with several different business models and means to capture value. They then focussed their initial offering (MLD1): *"So, our entry point is going to be the one that's easiest and quickest to validate and the fastest to adopt. In terms of unmet need, we think screening is the biggest opportunity, with a high value".*

Management and Capability Development

The MLD team developed by building on the skills of the team members, contractors, their network and by learning. Several of the team members who joined were experienced, and so able to enhance the organisations capabilities, but not all capabilities were acquired. Several routines (such as their quality Standard Operating Procedures) were developed through an initial design and then a trial and error process, so the process of building capability was largely evolutionary and experiential.

6.7 Case 5 – DH2

6.7.1 History and Background

The innovation organisation is a 'start-up', DH2, formed by an entrepreneur with a strong personal interest and extensive commercial experience. The focus of the organisation is to develop digital solutions (e.g., using mobile technologies) to improve patient care pathways, outcomes and experience, for diabetes and respiratory diseases. The innovations are convergent involving clinical and social care pathways, a range of wearable technologies and digital solutions (particularly analytics and 'big data').

The venture started in August 2013. The case research started during the second year of the venture's existence and followed the start-up until December 2015, so provides evidence through major milestones whereby significant investment and commitment was sought. As it turned out the venture failed, being unable to attract sufficient funding in enough time to maintain a competitive position versus other innovators. A post-mortem was carried out after the venture failed to better understand the factors that they believed impacted this.

A summary timeline, highlighting key events in the case history is provided in Table 6-12.

6.7.2 Case Evidence

Case Research followed the methodology developed in Section 4. During the case study, data was collected from interviews, observations and, from public and company documents (obtained under a confidentiality agreement). A summary of the interviewees, observations and documents accessed is provided in Table 6-13. Further information on interviewees is provided in Appendix A4. Direct observation at meetings and workshops with innovators, investors and other key stakeholders also provided evidence of practices and capabilities. All data was securely stored on a confidential cloud server and uploaded into NVivo software for analysis.

Table 6-12 Case DH2 study key events

Date	Event
Aug 2013	Idea proposed (founder 1 part-time).
Nov 2013	Met GSK at Medical Day with Harper McCleod. Discussion led to follow up meeting.
Dec 2013	Introduced to Commercial lead and team in Respiratory Commercial at GSK. Some challenges – "sounds like great solution, but more pharmacy than pharmaceutical".
Jan 2014	Presented to Innovation Team (at GSK), based upon: software on mobile, with connected inhaler and wearable device (Fitbit like) to monitor activity and sleep, plus some respiratory indicators. Focus of pitch was on adherence. GSK want to see a demonstrator before they can decide.
Q1 2014	DH2 began to develop solution focused on adherence.
April 2014	DH2 formally registered in Companies House
May 2014	Working with IDEO in US, Health SF. USP pitched as "Condition PA". Got feedback to forget hardware, others will do that. Just pull in APIs. IDEO suggested interest, but concept needed more validation. Working with 3 entrepreneurial partners to develop design and business plan. Need €30k to progress.
	Working part-time whilst trying to raise funds for prototype
Sep 2014-March 2015	Pitched to Scottish Enterprise High Growth Start-up as potential investors. Being part of SE high growth programme, central belt, only 1% start-ups meet criteria, good DD for investors. Gave £5k grant to create demonstrator. Put in front of Walgreen (Pharmacy) and got positive feedback, they put DH2 in touch with Apple. They wanted to showcase internally but DH2 didn't give permission. Have an initial non-working prototype and some specifications for the device, app and data analytics that are required. Decided to focus on asthma and with pharmacies, although pharma remains the priority.
April 2015	CEO moved to full-time – effort is more on fund raising and trying to identify work with/engage strategic partners. For Walgreens, we made decision from financial plan, to park until further down line. As DH2 would have had to develop and manufacture hardware.
May 2015	Case Started
Jun 2015	Had follow up meeting in June with GSK commercial Director. Out of GSK meeting, it was determined that they also needed hardware. DH2 plan to stick to asthma, but with pharma. But GSK are so slow (or less interested as have own developments); so, AZ also considered as next partner option.
Jun 2015	Chair instrumental in identifying key people for team. They put team together for a few weeks. From May to June in 'acting capacity' to see who committed and how they worked together. Gave them exposure to the project, DH2, and each other. From interview feedback they believe it went well and had makings of strong experienced team
Jul 2105	DH2 have hardware specification for device and software specification (software engineers that Chairman has used before, more than just programmers, they are data scientists, and into analytics). DH2 started work on the User Interface (UI) and the data science models, and early coding stage, but not usable yet.
Aug 2015	Strategy 1 – DH2 have defined a route to market. Focus is on Asthma. Focus on big pharma as target customer, with UK/EU target geography, and offering SaaS. Strategy 1 aiming to raise funding in three tranches - £150k, then £250k, then £800k (for launch). Strategy 2 - (on back burner, due to need to focus) target would be diabetes. Customers would be Pharmacies- like Walgreens but the geography would be USA (v UK/EU) and we would be via a licence rather than offer SaaS. DH2 in discussions to set up meetings with VCs and high net worth individuals (HNWI) as potential investors.
Sep 2015	Found out about Adherium's IPO (New Zealand start-up with a Aus $35M prospectus) the day before DH2 were due to see the first round of major investors. As a result, DH2 declined the pitch. DH2 then decided that they had lost too much time (versus competition) and did not have sufficient momentum to continue as per current business plan. They did not have well developed back-up plan. They perceived the risk to investors was too high, so valuations would suffer. Decided to review strategic options.
Dec 2015	Following review, the Venture was terminated in December. Post-mortem interview conducted with DH1-1. Main aspects appeared to be lack of understanding of emerging ecosystem (esp. competitors), some internal commitment issues and delays in obtaining funding seen as main causes by Chairman. Case closed.
Dec 2016	Firm formally removed from Companies House register

Table 6-13 Case DH2 study data sources

Data Sources	Details	Aspects studied
Case Interviews	7 interviews of 2 senior managers and 1 other business leader over the case period, totalling over 7 hours (ranging from 45 mins to 90 mins).	Motive for venture. Innovation approaches used. Identification and development of network. Decision making.
Internal strategic documents	Master pitch deck. Internal email	To help verify the interview data and provide context.
Company Public Documents	2 communication and briefing documents	To help verify the interview data and provide context.
Academic, Business Press and Industry documents	6 Public documents including competitor documents, and partnering requirements	To help provide context.

6.7.3 Analysis

Coding followed the process described in Section 5. Initial coding was based upon the exploratory framework. The main events identified in the exploratory framework under factors F1 to F12 were summarised and then subject to the ECPO analysis to identify plausible mechanisms. The ECPO analysis for this case is included in Appendix A5.

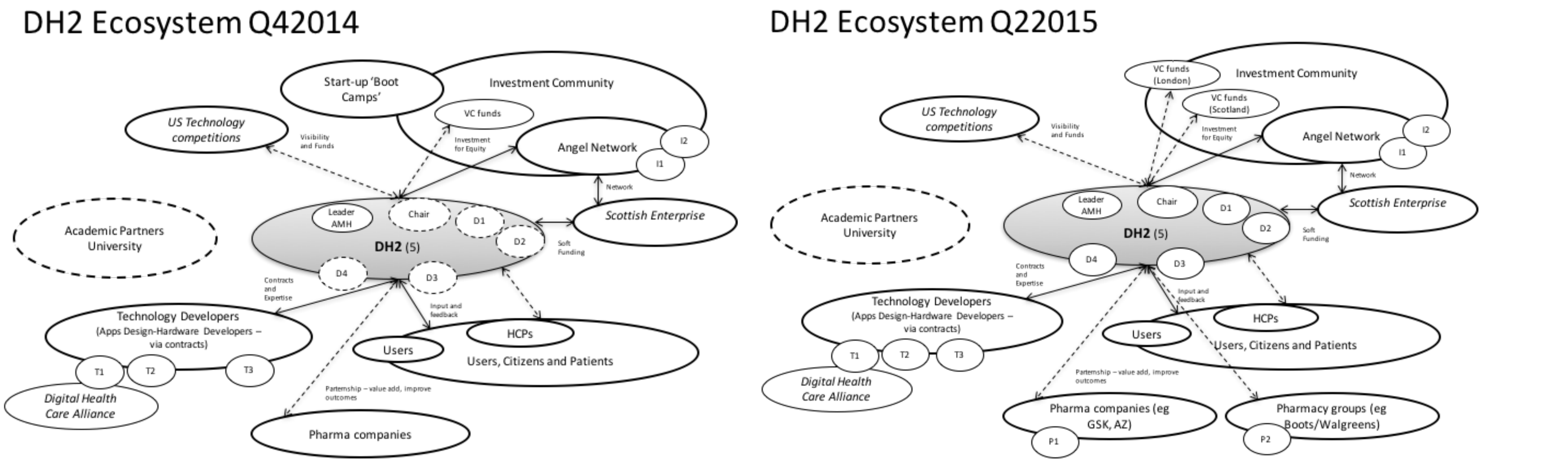

Figure 6-22 Case DH2 ecosystem evolution during case period

6.7.4 Findings

Ecosystem evolution

Evolution of Ecosystem over approximately 12-month period is shown in

Figure 6-22. For this case, it is noticeable that there is limited evolution and it remains focussed on a tight network of potential partners and investors. This is markedly different to other cases. Uniquely amongst the cases, they had no established academic partnerships or relationships.

The evidence suggests that the case firm was focussed a few key partnerships over the life of the venture (see Figure 6-23). The focus being 'big pharma', 'big pharmacy' and 'big tech' companies – but they found it difficult to obtain traction and make significant progress.

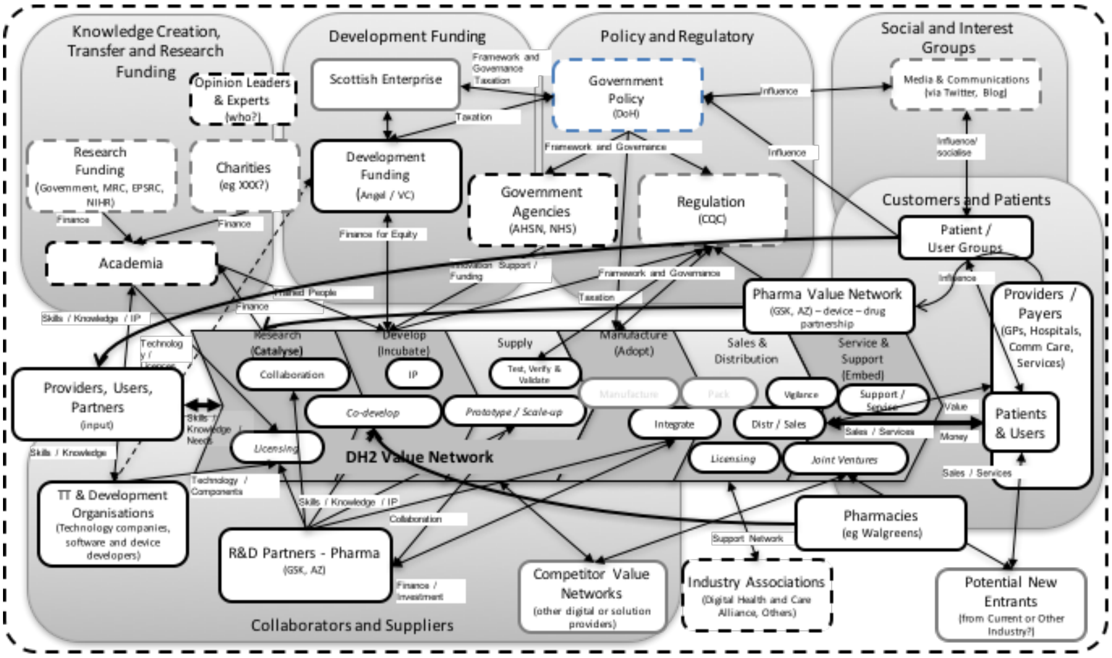

Figure 6-23 Case DH2 overall innovation ecosystem showing actor types and key relationships

Managing relations in ecosystem

The case firm had developed their innovation, via non-functional prototypes, up to specifications for a working prototype. But could not raise the immediate funding to progress the next step. Their funding search was initially focussed locally, on the back of receiving the Scottish Enterprise award, but they struggled to attract investors, despite interest from major partners. Several reasons for this are hypothesised and suggested by the case firm, ranging from limitations in the local investment community (as perceived by the CEO), to a lack of clarity in the business model and potential value. Consequently, they looked further afield for investors. Here too, they ran into challenges in terms of the value proposition and what market was best, with divergent views from different investors. The challenge as summarised by DH2-1 was: *"People have not really caught on to the fact that its a: Different opportunity, Different market, Different investor community".*

Their limited resources and limited engagement also meant they had frequent surprises as new actors emerged, DH2-1: *"[E] just arrived on our door a few weeks ago. We'd not planned it. But we need to decide quickly is it a go or not … We need to have a good reason as to why we'd come off strategy path one."*

These delays in building relations and finding investors, with the knock-on effect in terms of project delays, were probably a major contributor to the venture failing.

Building external credibility and legitimacy

DH2 followed a 'traditional' model of pitching to local enterprise board, getting some seed funding and interest, and then using that to build upon own network. Apart from formal meetings and repeated interactions with a few potential partners, there is limited evidence of engaging in the ecosystem more widely (i.e. with other tech start-ups or network organisations like DHACA). A consequence of this was they were often blind to other developments and one finally resulted in DH2 being terminated, as summarised (DH2-1): *"[AD] was like a big flag… a yellow warning. They had already got completed data. We knew about [N6], as they were called before they went public. [AD] is a great name, as its all about adherence. But it was a surprise. They announced at the IPO that they had 40 projects in 29 countries and 14 studies ongoing. But that was somewhat missed. We were under the impression they were doing environmental studies, but they were doing clinical. So, we were 12-18 months behind them".*

Value Network Development

Despite the increasing complexity as other ventures moved into a similar space, DH2 kept their own network tight. They made it clear that they wanted to work with one or two big partners and form a team around a few well-known individuals. This was perceived as keeping focus and reducing risk. What did become evident from the research and interviews was that they did not establish what value meant to different end customers and downstream partners and had conflicting feedback on this. This would indicate inadequate development of relationships and their value network.

Developing a business model and advantageous-position

Considerable time was spent reworking business plan and model. The process was iterative and evolved as they engaged with potential customers, investors and other opinion leaders. Almost all major organisations wanted more evidence before committing to invest or partner. They also got divergent views on where the value was – pharma thought it was pharmacy, investors thought it was payers. This not only impacted the potential customer and business model but also impacted the product design and service required.

Management and Capability Development

On paper the management team appeared strong (possibly the strongest of all the cases observed in this research, in terms of experience and seniority of previous roles). Despite this the venture failed. A post-mortem interview identified several perceived reasons for the venture failure. These were explained as a lack of understanding of ecosystem and competitor positions and delays in securing funding. From the analysis, there is evidence that the team's experience and strong governance may have been a contributing factor, in describing the CEO's action (DH2-1) stated: *"She can have lots of interesting conversations, but they might not help take her forwards. There has to be a reason; an intent".*

They appear to be highly reliant on their prior success and experience, but did not appear to fully recognise that the context was different. Also, having selected what they thought was the best model, they were reluctant to change "*without reason*", however the initial model was based upon information from limited engagement with ecosystem stakeholders.

Why do they adopt these approaches? - There was a strong belief they knew what the right solution is, and the right approach to fund and develop it. The CEO has personal experience of caring for people with the disease, and so has a strong personal drive to find a better solution. There was a sense that they needed to focus, as resources were tight, so alternative options were not developed. Where they undertook development, they moved to near complete solutions, as summarised by DH2-1: "*We have looked at strategic positioning. The software is specified, actually it's about 60% done (as a favour). We are close to having it fully specified. Then we had demo hardware. If you remember we had someone from FoxConn Europe. So, we had a device and Bluetooth. We had also worked out our Big Data app. But needed to confirm the algorithm."* So, they appear to have progressed the development significantly, but with limited external input.

The case findings are as not as clear as in other cases (e.g. DH1, NMD, MLD) but provides evidence of some search and sense-making activities. What is most striking is that these appear to be far less exploratory and engaging than other cases and the evidence for sustaining the ecosystem is weak. The fact that still venture failed may in part be because of limited search and sense-making before making selection decisions and as a result, failure to build stronger relations in the ecosystem.

7 Cross Case Analyses

7.1 Cross-Case Analyses and Review

As identified in the methodology (Chapter 4), in critical realism (CR) the cross-case analyses are not carried out in the last phase of the research, but data gathering and analyses take place in parallel, as there is a need for reflection as the research proceeds (Easton, 2010; Sayer, 1992). So, during the interviews and coding some analysis was undertaken to find similarities or differences between cases and then refine categories (for further coding) from that data (Saldaña, 2013). This also involved recoding earlier evidence as new categories were unearthed. In addition to coding, use was made of the *Memo feature* in NVivo (Bazeley and Jackson, 2013) to capture reflections and developing thoughts, which is recommended to aid research transparency (Bringer et al., 2004).

A consideration in the cross-case analyses, implicit within CR methodology, is that the context in each case is different so direct reading from one case to another requires care. Cross-case comparisons were largely interpretative, achieved by reviewing the evidence, context and emerging patterns and potential models. The researcher perspectives on these were captured in NVivo Memo feature and used to guide further coding and other analyses. Initial cross-case Memos followed the Exploratory Framework themes. As ideas and themes emerged other coding and new Memo notes were made to capture plausible explanations, these are described in the following sections.

7.2 Understanding the ecosystem and their relationships within it

As indicated above, as patterns emerged in each case, which were running in parallel, similarities and differences were explored and captured in NVivo (see example Appendix A6 Figure 1 Ecosystem understanding and relationship building). The first stage of cross-case analysis essentially addressed the research sub-question: *How do they manage relations in the ecosystem?*

All case firms initially struggled, unsurprisingly, with a lack of ecosystem understanding. Conceptually the ecosystem could be considered, as described in a recent systematic review of ecosystem literature (Aarikka-Stenroos and Ritala, 2017), as a 'category 2' (Aarikka-Stenroos and Ritala, 2017, fig. 1), with "new connections being formed". "replacing or disrupting existing ecosystems" and "blurry, emergent and non-linear boundaries"; all of which would add to the ambiguity and complexity.

Case NMD began by conducting a structured search and identified potential contacts and knowledge, but found the searches limited, so changed to a more explorative approach. DH1 were well connected locally, and from the outset sought to understand and connect by building relationships with a range of different actors. CMTI, like NMD, started with some structured searches, but then moved to exploratory searches to identify useful knowledge and new partners. From the outset MLD connected locally and used their existing network to expand to new connections. DH2 also explored new connections and networks, but appear to be more focussed, with less evidence of trying to connect distantly in knowledge terms. This is not surprising given limited resources.

There appears to be evidence of structured searches not working, at least initially. This could be explained by lack of codified information or knowing who to connect to. Several cases tried this approach, but then modified their search methods. Cases moved to use a more exploratory approach, by using the 'network of their network' to expand searches. They also searched via physical meetings, at conferences, one-to-one meetings and events, so searches appear to be intimately linked to building relationships and potential partners, as well as accessing knowledge. So, this 'understanding' process has multiple outcomes.

7.3 Customers and developing value propositions

A key step in developing an innovation is obtaining customer input to identify a value proposition (Khalifa, 2004). Evidence of customer engagement, developing business models and value propositions was reviewed and captured via NVivo Memos. An example of the memo development is shown in Appendix A6 Figure 2.

None of the cases had a well-defined business model for their new venture. Although DH1 'designed' a model using Osterwalder's 'Canvas' (2010), they ended up changing it and continued to evolve it during the research. This would add further weight to the argument that 'designing' a business model, is not viable in the context of an emerging ecosystems, and that a more evolutionary approach is required. NMD had not developed a business model (by the end of the case research) by intent, they explained this by stating that they wanted to wait for clinical data as they knew this was critical to their customer engagement. CMTI evolved their model and value proposition, narrowing it from their initial intent. It started with a broad model, aiming at supporting a wide range of 'convergence' activities, but over the course of time, they focused it, building more on their existing capabilities, rather than trying to move into a radically new area. MLD developed multiple business models, in part because their technology offered a potential 'platform' (Gawer and Cusumano, 2013). This then provided the means to offer different models for different customer types and they expected to use a combination of these. DH2 had an initial model defined, but on engagement with potential investors, changed it several times, ultimately, they struggled to find a business model and value proposition that worked across their multiple stakeholders.

All cases used a more evolutionary path to understand the value proposition and potential business models, they were not designed *per se*. They engaged via their networks and shared information with the intent of better understanding potential positioning of their innovation. Because of these engagements, they tended to make many minor changes to the proposed value proposition and business model. That also resulted in one case in changes to their value network (for example MLD moving to a mobile platform, and needing 'gaming-like' capability).

7.4 Identifying and manging potential partners

Having identified knowledge and actors in the ecosystem, a key step is then to form partnerships and value networks (Gilsing et al., 2008; Harrington and Srai, 2016) to create value.

All cases appeared to use transient relationships at first. Partnerships are typically formed for a specific outcome (i.e. to create data, or address a risk), that partnership might then be renewed or not, depending on whether it was needed for the next step and how the previous partnership had performed. Once a partnership was initiated, several innovators expressed the desire to work again with the same partner if the above criteria were met. Both NMD and DH1 identified the importance of not just seeking complementarities but also 'congruence', shared aims and values: "*I'd describe the common interest as something more, there needs to be 'congruence' a real alignment, not just in terms of the outcome, but also cultural and how you are going to do it.*" DH1-1.

Even if there was an opportunity to collaborate, other factors may influence an actor's decision to engage, [NMD]: "*You might expect them to be interested based on your prior knowledge, but it's not always like that, and it might just be timing or it doesn't fit their exact interest*".

In summary, in nascent ecosystems, forming partnerships appears to be more transient than existing literature would suggest. It is suggested that the reason for this is it enables the innovator to continue to explore the ecosystem and actors, and to identify and build necessary capabilities, but without long-term commitment until a suitable alliance partner (or optima) is identified. Appendix A6 Figure 3 provides an example of the cross-case NVivo Memo for partnership development.

7.5 Governance, leadership and decision making

The cases demonstrated a range of approaches to governing the innovation and supporting value network (see Appendix A6 Figure 4, for NVivo Memo). Unexpectedly in all the cases there was a need for agility. Established firms put in place mechanisms to provide an overall approval of the strategy, but then invariably used small empowered teams to execute it [NMD]: "*Once it's all approved we will have a highly empowered autonomous team to give us the agility we need*." Where more senior approval was required, the mechanisms are kept simple [NMD]: "*So, we were agile where we just needed [···] sign off on individual projects (after overall CET endorsement) using one pagers and probably got 90% approved."* Conceptually this aligns with the extant literature on managing potentially disruptive innovations in incumbent firms (Gwynne, 1997). The classic 'stage gates' (Cooper, 1990) were not evident. This can be explained because the criteria could not be sufficiently defined and the innovation process itself was still evolving, so decision points for the new technologies were not established. However this does not mean there was an absence of governance, but that a more directional and strategic approach was required.

Smaller organizations used a range of approaches to provide effective governance, but key is the maintenance of regular contact, for example [MLD]: *"··· we are still managing most of our work through informal meetings, emails, Skype calls etc. We keep our formal meetings to a minimum. It seems to work, our partners seem happy with the approach and we continue to make progress*."

When questioned about ability to use existing governance structures (in larger firms) they responded, that they were generally inappropriate [NMD]: "*it's not in their remit. And they don't have the right members. So, we are bringing in external ones, from medical devices, tech company backgrounds. It may be three internals, three externals or four internals and four externals. But not bigger than that*." The key issue being suggested was that existing structures did not have the required knowledge and capabilities to make the necessary judgments. Interestingly, large organizations were prepared to engage the ecosystem and collaborators to ensure that investment decision criteria made sense [NMD]: "*The team has worked together with a group of subject matter experts to define the following detailed success criteria, building on high-level specifications for the device and its functionality*."

Both DH1 and NMD (large incumbent organisations) and CMTI (medium sized incumbent) employed small dedicated teams with access to diverse external resources. They all described a desire to work in a lean, agile way, with 'virtual' teams of external expertise. These teams all had good sponsorship from senior leaders and highly credible leaders (who were trusted internally). This combination of supportive sponsorship and trusted capable leaders, appears to be important in enabling teams to act in an 'action-orientated' way, aligned around the venture, rather than being encumbered by bureaucracy or extensive internal debate. It may also suggest that the team should align its innovation culture around the technology with the fastest 'clockspeed' (Fine, 1998) in the 'convergence', albeit with appropriate checks for safety and regulatory requirements. So, for example DH1 aligned around digital and mobile approaches, rather than clinical pathways. Similarly, NMD initially aligned around emerging biology and around electronics and materials technologies, rather than traditional pharmaceutical approaches. This suggest that teams should be small, with trusted, highly capable and intuitive leaders, working extensively with diverse external partners in as agile a way as regulation and safety permit.

This evidence points to the need for agile governance, with directional, rather than defined decision criteria. Given the inherent risks in convergent innovation, making use of the wider network is valuable in helping to validate investment decisions or reduce uncertainty. Importantly, it also appears to reduce the risk of inertia, internal filters or biases in the decision process.

7.6 Comparison of large (incumbent) and small (start-up) organisations

Although there are a limited number of cases, a simple analysis of larger organisations (NMD, DH1 and CMTI) and start-ups (DH2 and MLD) was conducted (Appendix A6 Figure 5). Surprisingly, there were many similarities. Both large and small cases evolved their innovation processes. Both needed to create a position of 'credibility' in the emerging ecosystem. Importantly this was identified as important even for large organisations where the ecosystem was new or they were seen to be new to the ecosystem. Both large and small firms were prepared to adopt transient relationships and use agile governance. The main differences stem from the large organisations need to adapt their existing process and provide a degree of separation from the existing organisation, especially early in the development. Smaller firms (MLD and DH2) lacked physical and financial resources and so could not make significant commitments or investments in the ecosystem in the same way as larger firms (DH1 and NMD), but nonetheless recognised a need to remain connected and build relationships, thus needing to invest time and effort to establish position in their ecosystem.

7.7 Micro-processes underpinning the innovation activities

From the above analyses, it is evident that across all five cases some similarities in activities and underlying approaches were present. The ECPO analyses for the cases suggested some common causal mechanisms, it is postulated that these are 'micro-processes' than underpin innovation capabilities.

The evidence points to a need for *searching,* for both knowledge and for new partners in the emerging ecosystem in all the cases. These searches are not systematic (although may have started so), but rely more on an exploratory, evolutionary approach to seek out distant knowledge and partners. The searches are accompanied by a *sense-making* (and, importantly, *sense-giving*) process to enable innovators to exchange knowledge with other actors or identify other actors to engage. Many of these exchanges appear to take place face-to-face, and so social aspects help in the sense-making and sense-giving aspects. There is then a need to make a selection, or decision. No firm has infinite resources, so decisions are fundamentally about using their available resources to invest in the innovation or address a risk or support part of the ecosystem likely to be critical for success. The investment decision making process appears to use broad criteria rather than strict criteria or 'stage gates' (Cooper, 2008). An example of the NVivo Memo for these micro-processes is shown in Appendix A6 Figure 6.

As part of the CR methodology, alternative explanations were also explored, so that the most plausible explanation could be identified. As well as conducting this analysis for each case, a wider cross-case analysis was conducted identifying a range of alternative, theory driven, explanations for the observations. These are exemplified in **Error! Reference source not found.**. These analyses drawn upon several alternative theories. Some provide a plausible but incomplete explanation.

The five micro-processes suggested by the case and cross-case analyses are summarised in Table 7-1 to Table 7-5.

Table 7-1 Searching: evidence and insights from cases

Process	Example Case Evidence	Insights
Searching (strategic and creative) Sources: (Garud 2012; Pandza 2009)	• *"So, … it was structured to an extent. A bit like a structured fishing expedition. We tried many different ways".* NMD • *"It's fairly structured. We started with people we know. But are now expanding the interviews, talking to their suggested contacts. We want to extend our search beyond the usual suspects".* CMTI. • *"We had the concept, but we didn't know anyone in the field [xxx] or anything related… So we sent a cold call emails out to the likely stakeholders. We probably only got a couple back. But we had a discussion with them and they introduced us to others."* MLD	Searches are often a combination of structured searching (of known domains) and (often) snowballing, using the network of your network to expand the search to new areas, but in a structured way to help address *'distant'* knowledge

Table 7-2 Sense-making: evidence and insights from cases

Process	Example Case Evidence	Insights
Sense-making (and sense-giving) Sources: (Sitoh et al., 2014; Thomas et al., 1993; Weick, 1995)	• *"So it's like a bit like a deep dive in…and reflecting and then looking in another area…an iterative process…and trying to make sense of it, so do I have enough information, is it meaningful? Can I identify a hypothesis?"* NMD • *".. focused mainly on the value proposition, who the key customers were and then how to identify key stakeholders (in clinical) to help create 'pull'.* MLD • *"Another approach is that Conferences rarely engage patients. We are therefore going to run a one day (un)conference – that helps positioning – on 'people driven' health and well being, … So the input is all from personal experience, and participant led"* DH1 • *"We want some diversity"* CMTI • *"To be honest, it's a bit like Brownian motion. You are forever moving around, bumping into different people. And you cannot predict before hand whether they will add value or not, or even immediately after….You might expect them to be interested based on your prior knowledge, but its not always like that, and it might just be timing or it doesn't fit their exact interest" MLD*	Sense-making through developing 'propositions' and wide engagement in ecosystem, often going beyond immediate contact and network to 'test' the idea Involving the 'unusual' suspects helps improve the sense-making process. The ability to connect and make-sense depends not just on content, but on timing and mutual interest (and the stakeholders' current priority). Sense-giving is important to build credibility and engage ecosystem actors.

Table 7-3 Selecting: evidence and insights from cases

Process	Example Case Evidence	Insights
Selecting Sources: (Daft and Weick, 1984; Dean Jr and Sharfman, 1996)	• *"The hard choice is going to be – how much do we have a starting point that is much simpler and cruder than the ultimate goal, but while still maintaining a strategic differentiation from the [xxx] industry of today?"* NMD • *"…, after the community identified the 'problem' we went out and consulted to confirm we had identified the right problem and decision criteria, … and finally we checked that the community would be prepared to participate. So it was methodical, but it evolved"* NMD • *So we knew that technologically it was different, that we'd need different criteria and that things like safety data would be different to a molecular medicine. So we'd also need to judge the portfolio using different criteria.* NMD • *"We have introduced new decision points – Providers need to provide data at Discovery Day… If we progress, we build a prototype and seek further use/provider feedback. Again, if no demand, or prototype and spec are not right we can pull out…"* DH1	Selection often involves broad strategic aims, rather than precise criteria and tries to balance making near-term progress against longer strategic aims. Engaging the ecosystem in defining success also helps to build confidence in the decision-making process. The decision is more about interpretation than process in an uncertain environment

Table 7-4 Shaping: evidence and insights from cases

Process	Example Case Evidence	Insights
Shaping Sources: (Chandler et al., 2011; Read and Sarasvathy, 2005; Sitoh et al., 2014)	• *"We were a driver behind the concept of BE, with people wonder why we are in this are? and why are we calling it BE and not neuromodulation like everyone else. But people are now beginning to realise the potential. [investment] represents a sort of transition…. It's more than just developing technology"* NMD • *"So to start, we are probably going to position ourselves in 'convergence' as a 'Future Health Campus'. That will encompass Regenerative Medicine, Precision Medicine, Bioelectronics and Digital Health, which is sort of pervasive."* CMTI • *We are reasonably well known locally, so people come looking for us too. More broadly we are connected to NIB and some of their work streams; so that gives us an opportunity to influence at national level, particularly on Open Source software strategy.* DH1	Innovators invest time in helping shape the ecosystem and create a compelling 'vision' as well as driving the innovation itself. Shaping can be by influence rather than direct enactment or physical capability building.

Table 7-5 Sustaining: evidence and insights from cases

Process	Example Case Evidence	Insights
Sustaining (Smith 2013; Rong 2013)	• *"So, you have to invest in relationships, and it consumes your resources. But back to our network, we are building it, we have the first few critical ones in place and then we are working through them, to see more."* MLD • *"We have done something that is very distinct from other OI ventures. We want there to be broader access to the platform to help move the science forward. We see this as a 'Grand Challenge' a bit like HGP. So we have said we will allow the winner to retain the IP, but with conditions. Those are: they must make it broadly accessible to the community. [NMD] has the 1st option to license it to research and clinical use."* NMD • *"Investments internally at [NMD] will be held at a minimum during the exploratory years with all hands-on R&D taking place at partnering organisations and with the [NMD] team being lean and focused on evaluating, coalescing funding, and strategically integrating different strands."* NMD • *How can we find out who's key and engage them? Or which offering is most tractable? To reduce risk"* MLD • *"We are well connected locally and continue to spend a lot of time networking. We are always making new connections…. More broadly we are connected to [National Groups] …; so that gives us an opportunity to influence at national level"* DH1	Investment not just in the technology or innovation, but in the wider ecosystem, and in relationships In order to sustain the innovation, risk reduction is critical and needs to be addressed early without losing sight of long term objective. Innovators may actively build and nurture, engaging at all levels influencing and funding to create a viable ecosystem. Start-up and SME's are less likely to undertake major shaping activities, like funding wider ecosystem activities, but they still need to invest in continuing to build connections, network and access to ecosystem resources.

These tables highlight the source extant literature to support the proposed process, some example case evidence and broader insights from the cases. This combination of *searching, sense-making* (and giving) and *selection* are common to all cases. These three processes appear to be antecedents or pre-cursors to two types of investment, described here as *shaping* (Table 7-4) and *sustaining (*Table 7-5).

The cross-case evidence for 'sustaining' appears to show two distinct patterns. Large organisations, with access to considerable resources appear to be prepared to go beyond just supporting their immediate venture. Given the nascent nature of the ecosystem, there is a need to help 'kick start' the whole field. As described by NMD-1: *"But its actually more about stimulating the ecosystem, in practice we cannot access that funding, only academics can. It might seem a little altruistic but it's really about helping to catalyze the field".* Similar sentiments were expressed by DH1 and CMTI. The investment is more than altruistic, it's a recognition of the need to invest for the longer-term to create potential value. For the smaller organisations, this is not an option, they do not have adequate resources and funds. Instead they seek to build and maintain relationships, even if not immediately valuable.

Whilst these five 'micro-processes' appear to underpin the innovation activities, they do not appear to create or transform organizational capabilities *per se*. In that sense they are not dynamic capabilities, although they bear some similarities to Teece's (2007) 'sense, seize and transform' they are conceptually different. This is addressed in more depth in the later Discussion chapter. As these 'micro-processes' are repeatedly used and appear to form patterns they can be considered as characteristic of organisational routines (Becker, 2004; Nelson and Winter, 1982), that form the basis on an innovation capability. These patterns are discussed below.

Having identified similar patterns of processes in each case, a further review was undertaken to assess the extent to which these processes co-occurred. For example, in the coding, did references to 'searching' and 'sense-making' tend to occur together?

The analysis (Appendix **Error! Reference source not found.**), shows the extent to which each of the 5S micro-processes co-occurred and may be inter-related, providing an insight to how these processes operate together, rather than in isolation (Table 7-6). The consistency of patterns of searching, sense-making and selecting co-existing across all cases, suggest these work together. The evidence for other patterns of co-existence is less strong, but it suggested that the searching, sense-making and selecting work to enable either shaping decisions (the primary objective of an innovator) or sustaining (to help de-risk the innovation and environment).

An inference from this is that the proposed micro-processes act together in 'activity systems' (Rivkin and Siggelkow, 2007; Siggelkow and Porter, 2008). In four of the cases there is evidence that the micro-processes of search, sense-making and selection operate as a 'system', herein named '*navigate'*, as innovators attempt to explore and understand the ecosystem. The micro-processes of sense-making (and sense-giving), selection and shaping form a 'system' named here as '*negotiate*' as innovators uses knowledge and understand to make decisions and create or shape a position with other actors. The final cluster sense-make, select and sustain, reflect the need to invest in activities that support the innovation, but may not directly contribute to its creation.

Table 7-6 Analysis of 5S process co-occurrences across cases

Case	Total Case interviews (when analysed)	Activity system 'cluster'	Coding - 5S micro-Processes	Interviewees with coding	Coding Occurences	Comments - Notes and exmaples
CMTI	6	Navigate	Search - Sense	3	8	Extrensive evidence of systematic and snowball searches
		Navigate	Sense - Select	3	4	Building 'database' of ecosystem
		Navigate	Search - Select	1	2	To help make sense and support decisions
		Navigate	Search - Sense - Select	1	2	Have identified fields they will support
		Negotiate	Select - Shape	2	2	Engaging firms and investors
		Negotiate	Sense - Shape	2	5	Seeking feedback from them
		Negotiate	Sense - Select - Shape	3	3	engaging investors, wider community to help shape
		Nurture	Select - Sustain	4	7	have idenfited investments need to support ecosystem
		Nurture	Sense - Sustain	2	4	working on obtaining funding
		Nurture	Select - Shape - Sustain	4	5	
NMD	12	Navigate	Search - Sense	6	9	extensive search - systematic, then more exploratory
		Navigate	Sense - Select	5	10	and sense-making processes, engaging widely
		Navigate	Search - Select	4	4	identified focus areas and partners
		Navigate	Search - Sense Select	3	5	continue to evolve partners
		Negotiate	Select - Shape	3	4	shaping ecosystem (conferecnes), engaging investors and funders
		Negotiate	Sense - Shape	3	9	seek feedback to support decisions
		Negotiate	Sense - Select - Shape	3	4	proactively managing ecosystem, identifying new networks
		Nurture	Select - Sustain	3	7	putting in place sustaining infrastructure, funding
		Nurture	Sense - Sustain	2	5	multiple investment streams, mlutiple development projects
		Nurture	Select - Shape - Sustain	1	2	
DH1	14	Navigate	Search - Sense	4	4	wide engagement, especially patient groups and practitioners
		Navigate	Sense - Select	2	2	use engagment to make sense and build business case
		Navigate	Search - Select	4	4	only progress projects with user/patient input and evidence
		Navigate	Search - Sense - Select	1	1	focus on things they know from customers are important
		Negotiate	Select - Shape	2	4	engage wider community to build ecosystem
		Negotiate	Sense - Shape	2	4	seen as key players locally and at National level, influence
		Negotiate	Sense - Select - Shape	1	1	access to funding, evolving business model for more flexibility
		Nurture	Select - Sustain	2	6	beginning to shape ecosystem
		Nurture	Sense - Sustain	3	6	looking to put code in open source repository for others to use
		Nurture	Select - Shape - Sustain	1	1	
MLD	10	Navigate	Search - Sense	4	13	lot of early searches, hard to find right connections
		Navigate	Sense - Select	4	4	engagements appear good, but often 'fail' . Need to keep searching
		Navigate	Search - Select	1	1	identifed potential partners
		Navigate	Search - Sense - Select	1	1	have developed value propositions based on stakeholder input
		Negotiate	Select - Shape	1	4	have reasonable idea on direction and shape of product / BM
		Negotiate	Sense - Shape	3	2	seeking investors to progress
		Negotiate	Sense - Select - Shape	2	2	investment in process
		Nurture	Select - Sustain	6	9	Have small network of support, building coalitition with practitioners
		Nurture	Sense - Sustain	4	4	Continue to manage networks, to maintain links
		Nurture	Select - Shape - Sustain	4	4	
DH2	5	Navigate	Search - Sense	1	2	much less evidence , of wide search, using known network
		Navigate	Sense - Select	1	1	limited 'search' - knowns only until late on, then realise not enough
		Navigate	Search - Select	0	0	made decisions on pathway with limited feedback and input??
		Navigate	Search - Sense - Select	0	0	no evidence?
		Negotiate	Select - Shape	1	1	maintain focus on original BM
		Negotiate	Sense - Shape	1	1	not clear on BM, keeps changing each time they engage.
		Negotiate	Sense - Select - Shape	1	1	identified competitors better funded and well aahead
		Nurture	Select - Sustain	0	0	re-checked interviews, lots of data, but little on shaping/sustaining
		Nurture	Sense - Sustain	0	0	no evidence?
		Nurture	Select - Shape - Sustain	0	0	

This could include providing support to partners, to help reduce risk, or enabling the development of knowledge or capabilities in the wider ecosystem, that can be drawn upon later.

It is interesting to note here that case DH2 shows the least evidence, even allowing for fewer interviews) than other cases. This would suggest that these processes were not as well established. This cluster is denoted '*nurture*' and could be considered similar to that discussed by Rong (Rong et al., 2013; Rong and Shi, 2015). However, a difference in perspective is that in this research the 'nurturing' is not simply that of the 'extended value network' or their 'innovation' as is largely suggested by innovation ecosystems literature (Adner and Kapoor, 2010; Autio and Thomas, 2014) but the wider ecosystem, thereby ensuring adequate institutional players and infrastructure support are in place. This is evident in the activities of NMD, DH1 and CMTI.

7.8 Credibility-seeking and Advantage-seeking activities

There is direct evidence from both the NMD and DH1 cases of the organisations engaging in activities to create a legitimate, credible and visible position (the use of these terms is defined here as - a position of *legitimacy* is one where your being present in the ecosystem is accepted, *credibility* comes from doing something tangible or having a position of power, and being visible is being recognised by others as doing so).

NMD built their position through engagement, enabling others to engage (via conference's), funding other researchers' work, curating a journal article and investing in start-ups. Their position on sharing IP helped address initial scepticism by academic researchers. DH1 started as a small venture, but worked with the local community of healthcare providers and patient groups to be credible 'connectors' and 'creators'. They then had to work further to build a credible position as deliverers and influence more widely in the ecosystem.

This position of *credibility* is suggested as an important precursor to adopting an advantage-seeking position. This approach is distinct from that in established ecosystems, where the innovator is (usually) already credible and may even have a dominant position. This implies an additional step is required for innovation in nascent or emerging ecosystems, and convergent innovation, where partners may not 'be seen as' natural inhabitants in the emerging ecosystem. This step appears to be required even for large organisations, if they move into a nascent or convergent field. Example evidence of how the case firms, particularly NMD, DH1 and CMTI achieved this are summarised in Table 7-7.

Table 7-7 Credibility-seeking and advantage-seeking actions

Credibility-seeking action		*Advantage seeking-action*	
Description	**Example Quote / Evidence**	**Description**	**Example Quote / Evidence**
Research Contracts share IP rights with academic R&D and other collaborators.	• "[collaborators] concerned…whether our IP position was genuine. … we said that everyone would retain their IP. And there was a lot of skepticism about whether we were genuine about that" – NMD • ".. 'white label products' and open source, so solutions can be shared as part of an open library, ..." DH1	Positioned as a 'hub' in network, and providing funds, support services and influencing research direction.	• "..what's turning into reality is that we are the downstream partners. So we can propose joint research with academics to apply for this funding…we believe that these funding programs can not only feed new ideas or new disease opportunities in to our development pipeline. But it's also a way for us to get more leverage in the early research." – NMD • [CMTI] will evolve the Open Innovation concept to address an emerging unmet need for company incubation and integration in the field of Convergent Medical Technology (CMT) in the UK. [CMTI] aims to identify disruptive technology for commercialisation that will provide solutions to biological problems and result in patient benefit longer term. – CMTI Strategic Plan
Funding start-ups via new corporate Venture Fund.	• "Through our $50m venture capital arm, [NMD] Venture Capital, we are investing in start-ups and technology platforms that aim to advance the development of bioelectronic medicines." [NMD website]	Renegotiated Collaboration IP positions to take full ownership (in return for royalties, funds) for later value capture.	• "Much of the value we've created has come from partnerships we've created with academics. The real balancing act this year has been to leverage the IP we've jointly created and use this …in a constructive way…we look to take control, via buy-out or licensing or royalties so we have exclusivity and ownership. – NMD
Create and fund Open Innovation challenge to address 'technology gaps' identified by ecosystem	• "… after the community identified the 'problem' we went out and consulted to confirm we had identified the right problem and decision criteria, … confirm this was critical and finally we checked that the community would be prepared to participate". - NMD	Hold right to exploit and capture value from Open Innovation IP for commercial use.	• "So we have said we will allow the winner to retain the IP, but with conditions. Those are: they must make it broadly accessible to the community. [NMD] has the 1st option to license it for research and clinical, commercial use". - NMD
Open access of IP from Open Innovation Challenge to research community.	• "Acceptance of the prize will require, .. that the .. winner … release all relevant research data and information into the public domain. This …will allow other investigators, including those at [NMD], the right to utilise the work for future research purposes while permitting the … winner … to retain commercial rights." –[NMD website]	Joint Venture formed with major technology partners.	• "So the driver was - how do we rapidly access the technology and engineering capability to build a game changing device". -NMD • "It's a big initial investment, so you want to be able to capture the value. So the deal needed to allow us to be able to capture the value." - NMD

Credibility-seeking action		*Advantage seeking-action*	
Description	**Example Quote / Evidence**	**Description**	**Example Quote / Evidence**
Develop paper for major scientific journal, to position the field and their role to attract other researchers and funding	• "Realizing the vision of a new class of medicines based on modulating the electrical signalling patterns of the peripheral nervous system needs a firm research foundation. Here, an interdisciplinary community puts forward a research roadmap for the next 5 years". [Nature 2014]	Influence on national level bodies to develop digital health strategy and policy	• "We are doing some work at National level, for NHS England. We are also working with Integrated Care Pioneers – conducting workshops and interviews to try and identify what are the barriers to digital in HCPs." – DH1
Special sessions at existing academic conferences to present collaborative R&D findings	• "we have now started to publically disclose the outcomes and output from all that funded work, through a number of channels" – NMD • "Our ecosystem is a lot bigger. It's mainly through networking. We attend and event or conference or we run an event for people." – DH1		
Creating visible content for others to engage with	• "It's also important that what we have done is visible, so people can see our track record. So, another important part of our role is to curate and make public. So, you will find searchable content on our website, in our blogs etc." – DH1		

7.9 Development of new capabilities

The small start-up organisations had few capabilities to start with. The case evidence suggests that they incrementally built capabilities, mainly through experiential learning. This is unsurprising and consistent with the extant literature. The evidence for this approach is less compelling for the incumbent firms. Whilst incumbent firms did evolve processes, based upon feedback and knowledge gained, their also made changes indicating they had a clearer picture of what needed to be done differently, pointing to a degree of management agency (Garud and Gehman, 2012).

Existing theory about dynamic capabilities and ambidextrous organisations do not adequately address these observations. For example, the dynamic capability perspective suggests that existent organisational routines for innovation could be deployed to create something radically new (di Stefano et al., 2014; Teece, 2012) but this implies they an incumbent firm (such as NMD or DH1) requires ambidextrous structures and appropriate social practices to balance exploitative and exploratory innovation.

Similarly, if exploratory new product development capabilities exist, embedded within an incumbent firm, then it is possible to argue that it could develop a disruptive technology without changes in organizational capabilities. An incumbent must confront technological and market uncertainties, but will unambiguously know *how* to act. This is not the case in the cases of NMD, DH1 and CMTI. They did not know how to act, but instead developed new approaches, using a combination of changes to existing routines, exploratory actions and management agency to guide decisions. The early reliance on replication of existing processes suggests any accompanying organizational capability will have continuity with the existing pool of organisational routines. This insight has implications for both the ambidexterity alternative and the dynamic capability concept. Changes in organizational capabilities are needed because the organisational routines adequate for navigating an established ecosystem are imperfect for navigating and *building* a nascent one.

The evidence from cases DH1 and NMD point to the skilful agency of managers in shaping processes and routines to meet the needs of the convergent innovation. For example, NMD adopted different approaches to open innovation and to corporate venture investments (than had been previously employed in the incumbent firm). Similarly, DH1 used more agile project management and decision processes from the outset, although they then evolved these. They both also used modified governance structures from the outset. This allowed them to negotiate the internal organisations and maintain an agile approach to the innovation, enabling them to engage and make use of the nascent ecosystem and actors. The question as to whether these represent dynamic capabilities is addressed in the later discussion (Chapter 8).

7.10 Implications for the proposed Convergent Innovation Framework

The Exploratory Framework was developed during the preliminary research phase, as both a proposed 'framework' and as an investigational tool. Based upon the case evidence and cross-case findings, an analysis of the original twelve factors (see Table 5-4) and these research findings was conducted.

The cross-case evidence suggests that some factors are probably less important than at first thought and there are several that could be recombined to provide a more holistic perspective. It is also evident that the factors themselves need some refinement to address the research findings, for example- F1: "*Firm undertakes activities to map and understand the ecosystem to keep pace with its evolution and develop it*" - appears too generic and does not adequately convey the difference in approaches identified in the case studies, and therefor required in convergent innovation. An alternative, and more precise, description of F1 is proposed as: "*Use active, exploratory and evolutionary searches to identify and understand diverse knowledge and actors. Develop from diffuse knowledge to more codified. Develop both knowledge and relationships to build a credible position in the nascent ecosystem, to enable later advantage-seeking actions*."

As another example, for the factor - F5: "*Map and understand key value creation and capture steps (linked to business model)*" - is better combined with the business model factor, F4, and re-worded as – "*Use the 'value proposition' as a vehicle to engage and refine offering. Identify value perspectives of customers and stakeholders. Refine business model to address pathway challenges. Integrate business model, innovation and value network development.*"

Similar revisions are proposed across all the original factors, as summarised in Figure 7-1. The final columns identify the suggested re-clustering and revised wording for the framework.

7.11 Cross-case summary

The cross-case analyses, although limited, identify several patterns that suggest potential models and frameworks (see Figure 7-2). These include: several micro-processes that underpin the innovation processes and capabilities, the use of these processes in an activity systems that enable innovators to *navigate, negotiate* and *nurture* their innovation, the need to establish legitimacy and then *credibility-seeking* behaviours before adopting *advantage-seeking* behaviours. Firms appear to evolve capabilities through a combination of skilfully managed small changes across multiple processes. Governance and decision making is agile, using stakeholders to help in guiding key decisions. These findings are now discussed in the light of the literature.

	Factor	Original Factor Wording	Strong Cross-Case Evidence for original factor	Navigate- search, sense-make, select	Negotiate - credibility and advantage-seeking	Nurture - shape and sustain	Governance - directional and diverse	Team capabilities, autonomy and agency	Value Networks - transient, flexible	Evolving Business Model - linked to innovation,	Capability changes - multiple broad and shallow	Integration and Risk Management	Rationale	Revised Factor Working	Revised Factor
				Extent that Research Findings are linked to or influence prior Factors											
F1	Ecosystem and Market understanding	Firm undertakes activities to map and understand the ecosystem to keep pace with its evolution and develop it.	Yes - NMD, DH1, CMTI, mld	High - critical to understanding ecosystems and its evolution	Med -- need to understand and build credibility	Med - delivering tangible outputs important to build credibility		High - core team needs diverse skills, judgement and empowerment so can operate broadly and		High - ecosystem and customers needs evolve, so maintaining understanding critial to business	Med- approach to understanding ecosystem evolves		Refine wording to address need to search and sense-make	Use active, exploratory and evolutionary searches to identify and understand diverse knowledge and actors. Develop from diffuse knowledge to more codified. Develop both knowledge and relationships to build a	Ecosystem understanding and relationships within it
F2	Stakeholder Management	Map and engage stakeholders through the life-cycle of the development process to facilitate progress, and evolve relationships over time.	Yes - NMD, DH1, CMTI, mld	High - critical to understanding stakeholders and their needs	Med -- need to understand and build credibility	High - delivering tangible outputs important to build credibility and advantage position	Med - external experts and stakeholders provide broader capability and challenge to key investment	Med - core team needs good skills in buidling credibility and relations with external actors	High -- need to understand and build credibility to access the right partners	High - ecosystem and stakeholders perceptions evolve, so maintaining understanding			Include in refined Ecosystem Understanding factor		
F3	Customer Engagement	Routines and capabilities to engage early in the development process with customers to inform product/service design and the potential business model options	Yes - DH1, MLD	High - critical to understanding who the 'right' customers to engage are	Med -- need to understand and build credibility	High - delivering tangible outputs important to build credibility and advantage		Med - core team needs good skills in engaging with potential customers		High - ecosystem and customers needs evolve, so maintaining understanding critial to			Refine wording to address need to manage wider ecosystem relationships	Engage potential customers and users early, and maintain engaging througout development. Use to address innovation and adoption challenges.	Customer engagement
F4	Business Model development	Map and understand the links between the business model and the required activities and capabilities.	Yes - DH1, MLD	Med- need to identify key customers and decision makers to provide input	High- need to repeatedly engage to evolve understanding, credibility and eventual	Med - need to invest in innovation (value proposition) and business model				High - ecosystem and customers needs evolve, so maintaining understanding critial to	Med- approach to understanding ecosystem evolves	Med - need to integrate BM risks with other risks	Refine wording to address need to manage wider ecosystem relationships	Use the 'value proposition' as a vehicle to engage and refine offering. Identify value perspectives of customers and stakeholders. Refine business model to address pathway challenges.	Business model development and integration
F5	Value Attributes	Map and understand key value creation and capture steps (linked to business model)	Yes - DH1, MLD							Med - value attributes only part of assessment needed to build business			Include in Business model development		
F6	Governance	Active senior management support and engagement in investment decisions. Adequate knowledge for project selection and progression through objective decision gates.	Yes - NMD, DH1, CMTI, but also needed to bring external expertise to support decisions.	Med - governance need broad understanding for key strategic and investment	Med - governance need broad understanding for key strategic and investment	Med - governance need broad understanding for key strategic and investment	High - governance team needs senior leadership to build internal acceptance,	High - governance team needs senior leadership to build internal acceptance,	Med - alliance management is flexible and light touch	Med - governance support neded to address conflicts between existing and	Med- governance also provides some early 'protection' in incumbent firms	Med - need to address integrated risks in governance	Refine to broader, directional criteria, with external or ecosystem input as key	Active senior management support and engagement in key investment decisions. Provide support to address intenal conflicts. Use external expertise to supplement and challenge	Flexible governance
F7	Gate Criteria	Objective Go / no go decision criteria to determine progressing to next phase, that consider external capabilities and paths.	No, use broad criteria and external ecosystem	Limited knowledge makes codifying requirements difficult, so			High - little evidence of defined criteria. Where used they are	Low - more reliant of knowledge and judgement of team, than defined criteria	Low - decisions on nascent value networks more about relational		Criteria evolve during development		Refine Factor to broader, directional criteria, with external or ecosystem input as key	Decision criteria are broad and directional, supported by external expertise or ecosystem actor input. Criteria are refined based on knowledge and progress.	Decision criteria
F8	Process	A process or methodology exists to guide process development and quality management	No, process evolves through broad, shallow changes				Low - governance processes are miniimal and evolve				High - limited processes in place. Use existing process and then make	Med - limited processes in place. Need to balance between Analytic and	Initial processes unlikely to be adequate. Muitple incremental but broad changes less likely to create risk or	Evolve processes, using broad but shallow approach to minimise risk and non-acceptance	Business processe and evolution
F9	Risk Management	Risk management processes are in place to address patient and user safety risks, and the combination of technological risks, product integrations risks and business and	Yes, but integration critical									High - need to address integrated risks	Existing Factor, requires refinement	Risk management in place to address integration of technological (including patient and user risks), business model risks, value	Integrated Risk Management
F10	Alliance Partners	Inter-organizational co-operation via clarity in objectives and scope. Accessing capabilities through alliance partners, adopting different alliance management approaches to different partners.	No, early clarity difficult. First steps are more about understanding, finding congruence - using transient	High - identifying potential partners challenging. Unlikely initial partners will be reatined in	Med- need flexible alliances.	Med - important to build credibility	High - governance team and external expertise to reduce risks	Med- core team need flexible approach to managing partners and alliances	High - building traansient VNs key to building credibility and capability.		Med- approach to understanding ecosystem evolves	Med - need to integrate BM risks with other risks	Refine wording to reflect need for building relationships and transient value networks	Use ecosystem relationships to develop flexible and transient value networks before committing to long term alliances.	Agile Value Networks
F11	Project Team	The core team has leadership, expertise and experience, and balances autonomy, accountability and empowerment within the governance framework	Yes - NMD, DH1, CMTI (less so in start-ups)					High - evidence that core team needs expertise, accountability and					No change	The core team has leadership, expertise and experience, and balances autonomy, accountability and empowerment within the governance framework	Empowered Project Team
F12	Support infrastructure	Firm builds and makes use of ecosystem and infrastructure to complement own capabilities and to support development of innovation culture	Yes, NMD, CMTI, DH1 - but more about helping build supporting infrastructure, as institutional gaps exist	Med- need to identify gaps in support infrastructure, which may evolve as needs change	Med - Providing support to ecosystem enhances negotiating position	High - providing tangible support important to build credibility and advantage		Med - evidence that core team needs ability to understand support nedds and find range	Med - support maybe provided from amongst value network partners				Refine wording to address need to support ecosystem infrastructure	Innovator invests in helping support (nurture) nascent ecosystem, addressing insitutional gaps, and contributes support to maintain viable infrastructure.	Support infrastructure

Figure 7-1 Revisions to convergent innovation framework from case evidence

		Cross-Case Evidence						
Causal Objects identified in Case ECPO analysis	Object	*CMTI*	*NMD*	*DH1*	*MLD*	*DH2*	**Proposed micro-processes**	**Activity Systems and Approach**
Search	o1	**Y**	**Y**	**Y**	**Y**	y	S1	Navigate
Sense-make	o2	**Y**	**Y**	**Y**	**Y**	y	S2	
Select	o3	**Y**	**Y**	**Y**	**Y**	y	S3	Negotiate
Shape	o4	**Y**	**Y**	**Y**	**Y**	y	S4	
Sustain	o5	**Y**	**Y**	**Y**	y	n	S5	Nurture
Legitimacy-seeking	o6	**Y**	**Y**	**Y**	Y	n	S4, S5	Legitimacy / Credibility
Advantage-seeking	o7	**Y**	**Y**	**Y**	y	y	S4, S5	Advantage
Broad-shallow capability development	o8	y	**Y**	**Y**	y	n/a	S3, S4, S5	Capability development
Nascent Value Network	o9	y	**Y**	**Y**	**Y**	n	S3, S4, S5	Relational approach
Agile governance	o10	**Y**	**Y**	**Y**	y	y	S3	Broad criteria *(engage externally)*

Key: **Y** - good evidence y - partial, n- none

Figure 7-2 Cross-Case ECPO analysis to support proposed causal mechanisms

8 Discussion

8.1 Introduction

In this chapter, the results and findings are discussed in the light of existing theory, with suggestions for new models, concepts and frameworks.

8.2 Ecosystem Understanding

Methodologies for understanding business and innovation ecosystems, especially nascent ones, are not well developed (Autio and Thomas, 2014; Oh et al., 2016). Consequently, tools for practitioners to understand these complex ecosystems are not readily available. Where people have studied ecosystems, it is often more by an analogy (den Hartigh and van Asseldonk, 2004; Oh et al., 2016) than any systems-based approach. As part of this research, a more systemic approach for studying ecosystems was developed. The implications of this and the potential to develop tools for practitioners are considered below.

The initial research phase in this study aimed to address *conceptual* aspects, including *ecosystem boundaries* and the key issues and *perspectives* of ecosystem actors. Analyses were undertaken to examine stakeholder influence, impact and identity, helping to determine the system's boundary and perspectives taken by actors. Boundary determination was by a *population-community-identity* approach (Post et al., 2007; Santos and Eisenhardt, 2005). Ecosystems were mapped at several levels to produce an overall map and more detailed views in and around specific issues such as investment funding. This provided an approach to address multi-level features inherent in any such system (Gupta et al., 2007; S. W. J. W. J. Kozlowski and Klein, 2000). It could be argued that in nascent ecosystems, this approach, is more appropriate than an alternative, such as using processes and functions (Post et al., 2007), as these have yet to be routinely established. It therefore suggests that approaches to boundary determination are linked to the ecosystem lifecycle.

As previously identified, convergence brings increased complexity. But the healthcare and innovation ecosystems already exhibit considerable complexity. Developed from the Phase 1 ecosystem interviews in this research, Figure 8-1 presents a top-level ecosystem map for healthcare innovation in the UK. It also represents the landscape into which all five cases were located.

Mapping at this level (as is often done) is considered inadequate to describe the nuances inherent in the ecosystem. To address this sub-system maps were developed (see section 6.2.2) using a combination of interview data and documentation. Methodologically they follow soft systems approaches (Checkland and Scholes, 1990). These provide an opportunity to explore specific processes and environments that represent context for case innovators' decisions and actions.

There is evidence that four cases organisations: DH1, NMD, MLD, and CMTI attempted to map their ecosystem and conduct stakeholder analyses. In some (NMD and CMTI), this was extensive, using a range of techniques. Others (DH1 and MLD) simply captured information from various encounters and events, then reviewed these. During the nascent phase of an ecosystem, these actors may change significantly, as some leave and new actors emerge, requiring any mapping to be dynamic.

A further challenge is the complexity of the value system where multiple 'customers' and other actors play critical roles in the adoption chain (Adner, 2012). Within healthcare systems there are different perspectives of value by different actors. The previously developed Figure 6-6depicts the system of patients, practitioners (such as physicians, doctors and nurses), providers (such as clinics and hospitals) or pharmacies and payers (government and private health insurers) (Department of Health- UK Government, 2013). Whilst these 'customers' may be the end user or payer, there are also other intermediaries that need to be considered, including organisations such as NHS Procurement who determine 'approved suppliers' and contract terms.

These challenges are not unique to the UK. A similar map could be drawn up for other countries and the 6Ps identified: patient, practitioner, provider, pharmacy, procurement and payers, can be found in most major healthcare systems (Thomson et al., 2013).

Another factor having significance for innovators was the limited institutional frameworks, making traditional innovation approaches less applicable

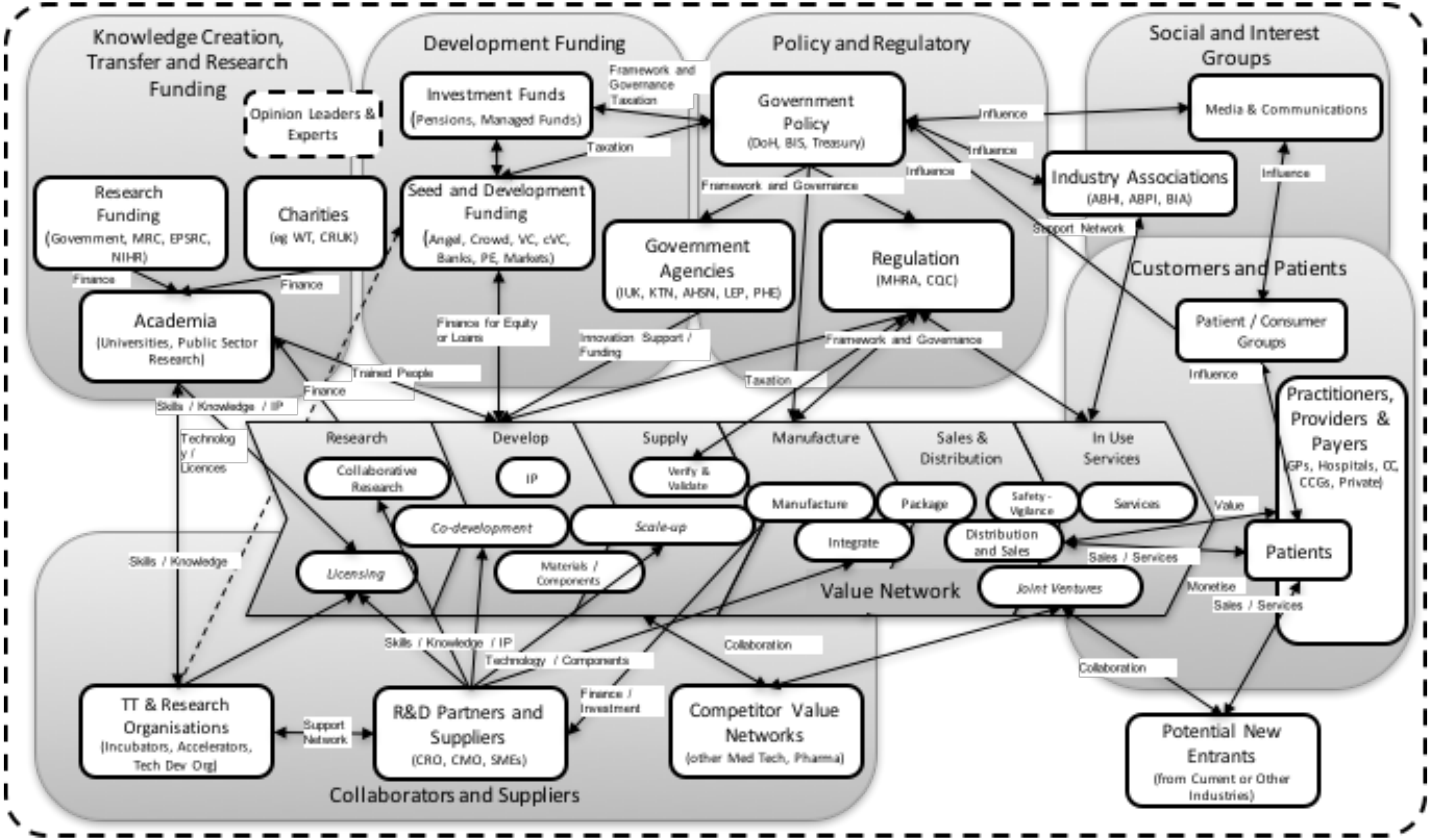

Figure 8-1 Overall UK healthcare innovation ecosystem

The method framework developed (see Table 4-3) provides the foundation for a tool set for practitioners. Whilst not developed here, such a framework could help innovators address the complexity through the concepts of perspectives, boundaries, structure and relationships, dynamics and co-evolution, provide a more thorough way to map and understand their ecosystems. The application of the framework and summary research method implications are discussed in Chapter 4. Using this methodology in the initial ecosystem research demonstrated that the conceptual, physical and temporal dimensions of ecosystems can be incorporated in an analysis of systems-based organizing. This approach may be of greater relevance in studying nascent or highly dynamic systems. By mapping ecosystems at multiple levels, further insights helped to explain aspects of the case firms' behaviour that were not apparent at the macro-level, such as access to investment funding. Furthermore, the nature and quality of relationships could only be determined by more detailed, lower level mapping. The use of a multiple snapshot view to understand system dynamics made it possible to map the evolution of the ecosystem and the case firms within it, illuminating how firms developed their value networks in these nascent ecosystems. This approach moves beyond previous structural mapping approaches (Moore, 1993; Rong and Shi, 2009) and those considering value and exchanges (Adner and Kapoor, 2008; Urmetzer et al., 2016) to explicitly consider relationships and the influence these have on activities and dynamics.

Whilst the approach and framework developed is potentially generic, it has only been applied in limited examples, and so would benefit from wider application, and testing, to help refine the methodology.

The initial research findings from the ecosystem interviews identify a complex environment, providing the context for innovation, where:

- Knowledge and capabilities are diffuse (and spread widely), and that diverse approaches and duplication of effort amongst actors is evident.
- The emerging ecosystem is not well understood, new agile entrants and new models are meeting risk averse and fragmented stakeholders.
- The emerging ecosystem contains organizations with wide variations in culture and capabilities, and typically, there is a lack of customer engagement and understanding of future business models.
- New assets and investments carry higher risk and have less understood investment decision criteria.
- Public R&D funding and venture capital investment are not well developed and, in addition, Regulation, Legal and IP issues are more ambiguous in the emerging ecosystem.

- The Value Networks and Supply Chains require new alliances and new models to address the lack of infrastructure and support organizations.

8.3 Underpinning Processes for Innovation

The following section discusses the proposed micro-processes (organisational routines) underpinning convergent innovation.

8.3.1 Searching

Some innovators used structured and systematic searches, at least initially. Some also used open innovation and crowdsourcing, but to limited effect. Why were these traditional search methods not effective in this environment? It is suggested there are two primary reasons for this, which are developed later in this chapter:

- to conduct a systematic search and to crowdsource, the issue or information required needs to be codified in some way. This implies a level of understanding that may not be initially available in convergent innovation.
- to attract others (e.g. to join a crowdsourced initiative) the innovator needs to be visible, legitimate and credible. The actor's engagement needs to be "seen as" valid by other actors.

Four of the five cases started with some systematic or crowdsourced type searches, but they evolved to more exploratory search processes. This often involved engaging the network of their network, using 'snowballing' to expand searches and using contacts from meetings and events to further their search. What appears key to many of the searches was building of some form of relationships with others.

Searching is considered strategic in the sense that it is critical to the venture (Pandza and Thorpe, 2009). So, it needs to be active, deliberate and directed (Zollo and Winter, 2002), but also creative, evolutionary and adaptive (Stack and Gartland, 2003). Interestingly, there was little evidence of using intermediaries or knowledge brokers as has been suggested by other authors (Birkinshaw et al., 2007; Obstfeld, 2005). This may, in part, be due to the nature of the convergence and the limited ability to codify knowledge and search requirements. It may also be, that such brokers with the relevant knowledge breadth did not exist or lacked credibility. Or, that with no clear domain and no leading actors, those with knowledge were simply unaware of other actors who may be relevant. Consequently, the cases engaged in exploratory searches that were strongly linked to direct engagement and building relationships.

Three cases (NMD, DH1 and CMTI) were instrumental in helping develop a knowledge ecosystem (Clarysse et al., 2014). This was most evident in the case NMD, where they funded conferences and events with the express aim of encouraging knowledge exchange and building the network understanding. They later pushed for special topics at established academic conferences to 'spread knowledge'. Similar knowledge sharing events were also curated by CMTI, who organised a series of workshops and summits. In case DH1 there were also deliberate attempts to create and curate events that fostered knowledge exchange across a diverse audience of patients, practitioners, providers, payers and developers. The early formation of a knowledge ecosystem (Valkokari, 2015) is consistent with the evolutionary path of convergence suggested by Hacklin and Wallin (2013). What the case evidence additionally suggests, is the need for innovators to actively participate in, and shape these activities.

8.3.2 Sense-making (and sense-giving)

The importance of sense-making in any new venture or innovation is well established (Garud et al., 2013; Sutcliffe et al., 2005; Weick, 1995). But there is also a need for sense-giving (Gioia and Chittipeddi, 1991) in order to engage potential collaborators and to help establish common understanding. It is suggested that this is achieved through the revealing of some knowledge through 'boundary objects' (Carlile, 2004, 2002; Leigh Star and Griesemer, 1989) which help others to understand through processes of transferring, translating and transforming (Carlile, 2004). Where the actors' domain knowledge is similar, a *transfer* process is adequate, but as the knowledge distance increases, there is a need to *translate* or *transform* that knowledge to enable exchange of understanding. Based on the case evidence, where knowledge and actors were often distant, the translate and transform approaches appear more evident and would explain the need for direct engagement, rather than via a third party or on-line search.

Given the inherent risks in exchanging knowledge with others (i.e., that you may give away intellectual property), there is evidence of 'selective revealing' (Alexy et al., 2013) as innovators navigate and negotiate a position. This was more evident in cases NMD and MLD and to some extent DH1. NMD set up collaborative agreements to ensure control of knowledge with rights to *both* parties, although the knowledge was pre-competitive and earlier than downstream exploitative processes (Valkokari, 2015). These agreements appeared to help build trust amongst diverse actors. NMD also chose to only partially reveal some aspects of their venture until they held some positional-advantage, as summarised by NMD-1: "… *for later work, that's more commercial, we are more opaque. I'm happy for the competition …. thinking or seeing this is just [NMD] working on a 'moonshot', 10 years away... and not being hopeful about being in the clinic in the next 3 years. But equally there is no benefit to overhype it. So, we want to make progress for the next year or so, first*".

So, there is a careful balancing act required: a need to engage, to be credible, to reveal and exchange, but also not give away value. The revealing is selective (Alexy et al., 2013). Building on a combination of case evidence, supported by prior literature, Figure 8-2 suggests a non-deterministic approach for how these exploratory and evolutionary processes may operate together, balancing knowledge-building processes with relationship-building processes. To explore boundaries, to find distant knowledge and partners, there is a 'divergent' phase, exploring breadth rather than depth (Laursen and Salter, 2006). Here snowballing is often used to extend the search. Several of the cases (NMD, CMTI, MLD) deliberately pushed their searches wide. This approach makes sense given the desire to access and obtain long-term value; Rivkin and Siggelkow (2007) identify that in complex systems, broader exploration delivers greater long-run value. Activities are aimed at basic understanding and building credibility. As knowledge is gained, enabling better codification, and as relationships are formed (increasing their network and legitimacy), crowdsourcing may become appropriate. Later the searches appear to converge, focussing on the network and knowledge of greatest value (and with move to exploitative actions).

8.3.3 Selecting

The approaches used by all cases to make decisions varied, but tended to use broad criteria, rather than specific 'decision gate' criteria, as often identified in the innovation literature (Cooper, 1990; Cooper and Kleinschmidt, 2007). This broad approach aligns more with thinking in "fuzzy front end" innovation (Khurana and Rosenthal, 1997; Koen et al., 2014, 2001). Several cases used ecosystem actors to help in decision processes. Case NMD used the ecosystem to help define the problem, the criteria and sense-check solutions as part of their open innovation challenge. Similarly, DH1 used stakeholders to define problems, shape solutions and provide information to underpin decisions. CMTI used the ecosystem to help shape their strategic decisions. This approach not only helps reduce risk, but also helps build relationships, a network position, increasing their perceived credibility and legitimacy.

Interestingly few innovators used partners they already had established relationships with (i.e. prior to the venture). The reasoning posed for this is that they are seeking new knowledge and complementary capabilities and in convergence these are unlikely to be in their existing value network. CMTI approached previous investors for funding, but also engaged new ones. The only case that significantly 'went back to people they already knew' was DH2.

8.3.4 Shaping

Innovation is essentially a creative process (Adner and Kapoor, 2008; Alvarez and Barney, 2007; Sydow et al., 2012), with a balancing of both path dependency and path creation processes (Sarasvathy, 2001; Sarasvathy and Dew, 2005) and may require path breaking (Aarikka-Stenroos and Ritala, 2016; Karim and Mitchell, 2000; Sydow et al., 2009). To do this firms need processes to synthesise the knowledge and potential partners across the ecosystem. There is evidence in all cases of firms attempting to and succeeding in shaping their innovations. The evidence is more nuanced however, in how firms undertook this.

NMD had a clear idea of where they wanted to be from the outset (as described in their 'White Paper'): "*Bioelectronics promises to be a major source of future medicines. The launch of … aims to give [NMD] a leadership position in this emerging field. A network of research partners with multiple disease test beds and gate keeper technologies will be integrated by a 'virtual' team with a £[X-Y]m budget … The output should crystallise the extent to which bioelectronics can be a sustainable [NMD] innovation leg.* However, the process to achieve this was not as clear. By engaging a nascent ecosystem, building a credible position within it, and by providing resources, they could take an increasingly central and influential position. That enabled them to shape, not only the innovation, but also the value network and wider ecosystem. In case DH1, although they did not make investments on the scale of NMD, they continually engaged the local ecosystem and built a network at national level that positioned them as credible and influential.

Case MLD, a start-up with limited positional power, relied more heavily on internal creative processes and then building relationships with a diverse range of partners. Initial attempts to find investors resulted in repeated failures, but these were overcome, by using less specialist investors and then using the 'network of their network' to find additional investors. Similarly, the value networks needed were developed through building on 'networks of their network', and engaging others with potentially complementary capabilities. At CMTI the shaping process was initially quite ambitious but after extensive engagement and review it became more about building on and extending capabilities and partnerships, and therefore appears to be more incremental in terms of approach. DH2 had a clear idea of their innovation and how they wanted to position it, but never managed to create a position of influence or credibility before options and funding ran out.

The inference from these cases is that 'shaping' an innovation, through creative processes is not sufficient. Unlike existing industries or established innovation ecosystems, both start-ups and large established firms (moving from their incumbent domain) must first establish this credibility and legitimacy. There are antecedents to the formation of value propositions and value networks.

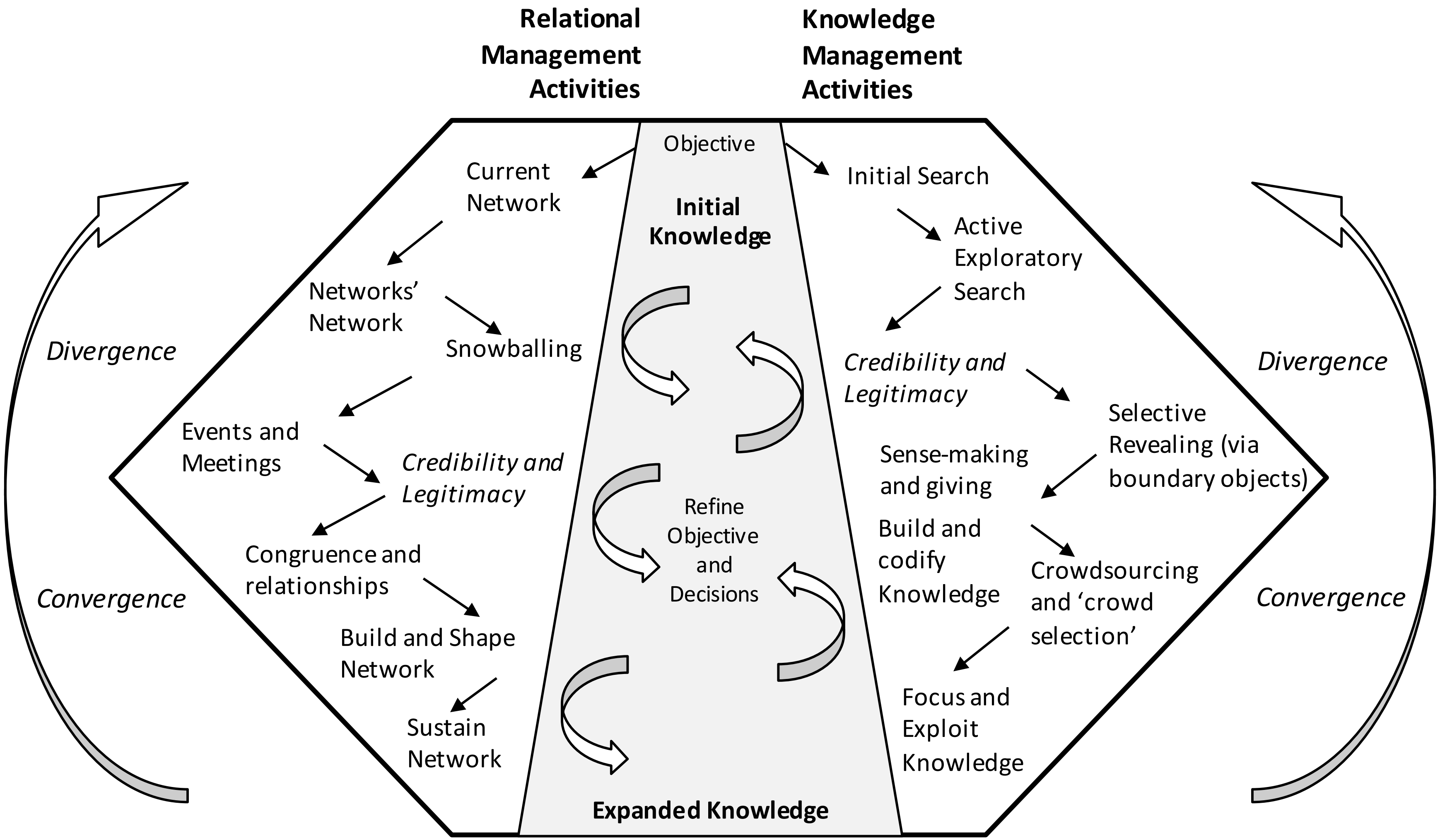

Figure 8-2 Evolutionary search and sense-making processes evident in case research

8.3.5 Sustaining

In any innovation, there is a need to invest in activities that de-risk the venture (Kayis et al., 2007). In several cases, there was evidence of investment in developing support capabilities, in the value network and even the wider ecosystem. Case NMD invested significantly in supporting other ecosystem actors (i.e., by sponsoring events and conferences), in funding an enabling technology (via an open innovation challenge) to address an ecosystem gap and directly supported actors by funding research and investing in start-ups. DH1 engaged and supported the wider ecosystem, by funding events (e.g. 'Discovery Days') and workshops. They also provided resources to other stakeholders on a *pro bono* basis (e.g., for a charity) as part of a culture of building relationships; described by the CEO (DH1-1) as: "*Connections do not just happen. You need to 'cultivate' to create the right opportunities. That is where I see this spirit of generosity and being open, learning together as being important*". Towards the end of the case period they were also exploring the possibility of creating an innovation space for other digital health start-ups, thereby further sustaining the ecosystem, and strengthening their position. Similarly, CMTI hosted events with the express intent of helping build a network.

For smaller start-ups, such as MLD and DH2, with limited resources, it is still important to build a position of credibility and trust. MLD maintained links with a diverse group of clinicians, venture funds and developers, and used these as opportunities to help develop their value proposition and value network; important precursors to obtaining investment. DH2 on the other hand, focussed on a much narrower set of actors, and this may have been a contributor to their failure.

8.3.6 Micro-processes for innovation

These five micro-processes appear to underpin all innovation activities, including the innovation itself, the development of the business model and the nascent value network. It should be pointed out at this juncture that whilst these processes are not dynamic capabilities. Dynamic capabilities are "*the capacity of an organization to purposefully create, extend, or modify its resource base*" (Helfat et al., 2007, p. 4), that is they are organization transformational processes, not innovation processes. The mechanism for the development of these innovation capabilities, and the relevance of dynamic capabilities, is further addressed in Section 8.8.

8.4 Innovation Activity System

It is suggested that these five micro-processes to – *searching, sense-making, selecting, shaping and sustaining* do not operate in isolation or in a linear manner, as is often depicted in innovation literature (see for example, Cooper, 1990; Cooper and Kleinschmidt, 2007). There is some inter-relation and sequencing (e.g., searching before sense-making). Reviewing the case evidence (see Chapter 7 cross-case analyses) suggests that searching, sense-making and selecting operate collectively, that then inform shaping and sustaining activities. But having made a sustaining or shaping decision there is a need to revisit the searching, sense-making and selecting as new knowledge, partners and decisions are required. These groupings of 'micro-processes' can therefore be conceived to operate as non-deterministic processes as part of an 'activity system' (Siggelkow and Porter, 2008) and the early formation of organisational routines (Becker, 2004; Nelson and Winter, 1982)

The proposed combinations of micro-processes are depicted in Figure 8-3 as three groupings in an activity system with phases that *navigate*, *negotiate* and then *nurture*.

8.4.1 Navigate

A nascent and emerging ecosystem, can be considered as an unfolding and evolving landscape. To understand and survive in this environment it is considered necessary to search and make sense, before making decisions (Kahneman and Tversky, 2007). These actions are largely pre-competitive, they are about building mutual understanding (Helfat and Peteraf, 2015). They require a degree of collective agency (Sydow et al., 2012) with both parties being prepared to exchange knowledge (as information or network contacts) through boundary objects (Carlile, 2004, 2002; Leigh Star and Griesemer, 1989) that enable the actors to transfer, translate or transform knowledge. Cases NMD, DH1 and CMTI used flexible approaches to identify, engage and build relationships. This was less evident in MLD, and almost non-existent in the case of DH2.

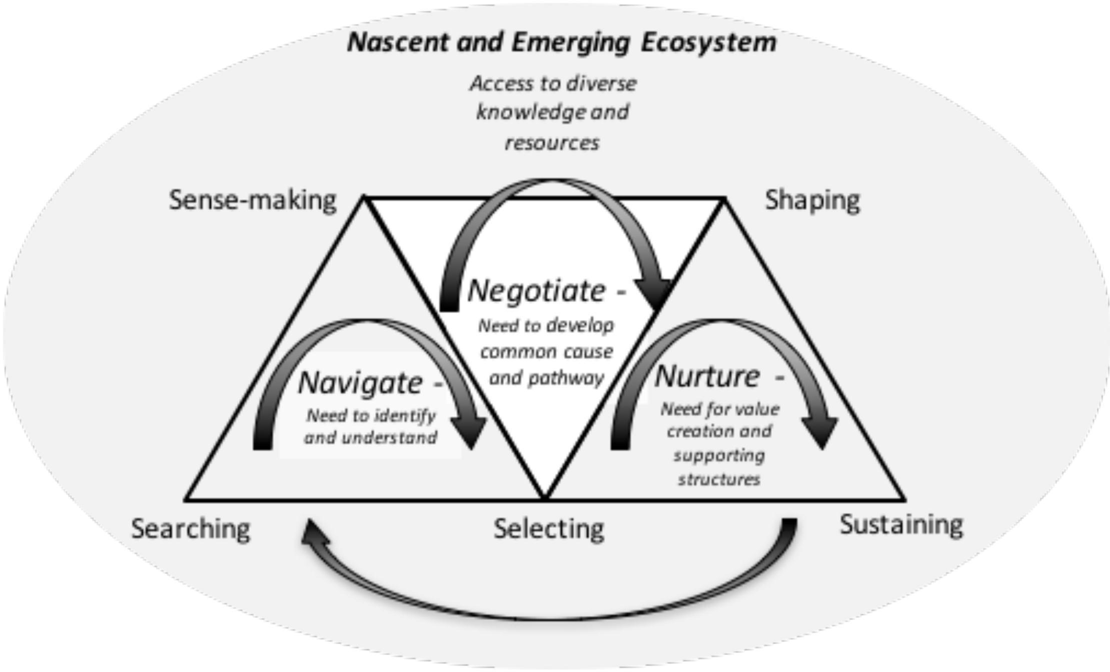

Figure 8-3 Navigate, Negotiate and Nurture as a convergent innovation activity system

At this stage the ecosystem could be considered as a knowledge ecosystem (Valkokari, 2015). The ecosystem is fluid, the focus of attention may move as new knowledge is gained (Dobusch and Schoeneborn, 2015) and as new actors join and leave. So, the knowledge ecosystem is evolutionary and can be considered incomplete (Garud et al., 2008). Knowledge ecosystems are not entirely self-organized due to the existence of some level of intentional action (Valkokari, 2015), here on the part of innovators. The case evidence shows DH1 and NMD as taking a co-ordinating role, and this being an intent for CMTI.

A challenge in this environment is searching too widely, losing efficiency as the knowledge distance extends (Nooteboom et al., 2007) or, searching too narrowly and missing opportunities (Enkel and Heil, 2014b). The evidence suggests that a moderating factor, aiding this navigation may be the relationships themselves. As these form, they enable organisations to make more informed choices about the depth and breadth of searches. Searching and sense-making processes are linked to the absorptive capacity (Cohen and Levinthal, 1990) and key to innovation capability (Ferreras-Méndez et al., 2015). The need for a wide search scope suggests a decentralised group and activity (Enkel and Heil, 2014b), which was evident in the cases studied. Larger organisations devolved the search processes to small, flexible organisations who were intimately engaged in the innovation.

8.4.2 Negotiate

To progress an innovation, there is a need to develop common cause and a pathway (Geels, 2005; Geels and Schot, 2007). Importantly the innovator must be able to 'take a position' and transition from exploratory activities to exploitative activities (Colombo et al., 2006; Kim and Atuahene-Gima, 2010). This requires innovators to address both positional and relational perspectives (Dyer and Kale, 2007).

To be able to negotiate there is a need for both credibility and legitimacy, and to be visible within the ecosystem (Aarikka-Stenroos and Lehtimaki, 2014). It is suggested that these result, in part, from the nurturing activities (below), whereby the innovator creates tangible outputs (demonstrating commitment), and supports others in the ecosystem. This was evident in the NMD and DH1 cases, who both committed to building a position of credibility, and providing support to the wider ecosystem. Case CMTI's strategy was to provide infrastructure and support to convergent ecosystems, but invested in building an understanding and partnerships before making a major commitment. MLD, whilst not having the resources to invest heavily in the ecosystem, nonetheless invested in maintaining diverse and strong relationships. This enabled the cases to access further knowledge and form new alliances (Wang and Rajagopalan, 2015), which are critical to access complementary capabilities or, to enhance their own capabilities. These partnerships were formed and re-formed by MLD, NMD, DH1 and CMTI. They can be viewed as non-deterministic where the outcome is not pre-ordained, equally they are not arbitrary, and have been described as *non-ergodic* (Sydow et al., 2012). This approach enables innovators to selectively reveal knowledge and their position (Alexy et al., 2013) as part of the negotiation process.

8.4.3 Nurture

The innovation environment under conditions of convergence are complex (Rikkiev and Mäkinen, 2013) with a lack of stable institutional support or frameworks. Further, the innovation may actually disrupt established institutional norms in terms of regulative (rules) , normative (values) and cultural (beliefs) elements (Scott, 1995, p. 56). Such innovations may disrupt entire ecosystems (Ansari et al., 2016) or create entirely new ones. As previously identified there is a need for *both* shaping and sustaining decisions to progress an innovation. These were most evident in NMD and DH1, but were present to some degree in MLD and CMTI. This combination supports the argument for both path creation and path dependent approaches (Sydow et al., 2012). These activities often go beyond those needed for the immediate innovation, but may provide support to the wider ecosystem, in a form of '*nurturing*' (Rong et al., 2013). These nurturing activities, creating outputs and new knowledge on the one hand and supporting others, and the wider ecosystem, on the other hand - are suggested as key parts of a process to build legitimacy and credibility, and in building relationships as well as knowledge. Furthermore, it is suggested that these are pre-cursors to building an 'advantage-seeking' position.

8.5 Nascent Value Network Formation

As convergence requires new capabilities (Enkel and Heil, 2014b), the organization has a number of options for building, acquiring or accessing these (Barney, 1999; Gulati et al., 2012). Given the challenges in internal development or in outright acquisition, alliance formation and management (Schreiner et al., 2009) would appear to be a critical capability in the development of 'nascent value networks'. All five cases of attempted to build new value networks. However, these initially tended to be short-term or transient. The networks were often created for a specific purpose, to create knowledge, deliver defined output or address a known risk. Those networks then evolved as the needs of the innovator firm evolved.

Value networks are essential for innovators to deliver and appropriate value, but much of the extant literature focusses on established industries and relatively stable environments. Convergence creates conditions of higher uncertainty and instability. As a consequence, the traditional criteria (for examples, see Hitt, Dacin, Levitas, Arregle, & Borza, 2000; Li, Eden, Hitt, & Ireland, 2008), are not considered appropriate.

Traditional value network theory would suggest that higher levels of network integration are considered important indicators of performance (Prajogo and Olhager, 2012). However much of that extant research is focussed on established or mature industries. This research focussed on convergence and nascent ecosystems suggests that such an approach is less plausible. Early alliance formation requires a balancing of tendencies for both exploration and exploitation (Lavie and Rosenkopf, 2006), the evidence from this research suggests that the domain dictates that explorative action is required first. The search for insightful stakeholders and then sense-making is critical, but different stakeholders have different (and sometimes conflicting) perspectives about value (Garriga, 2014). Diversity in innovation alliances is recognised as important (see for example, Nieto & Santamaria 2007), in many of the cases the innovators found that later collaborators were often not those they had engaged early on, and so building flexibility into the collaboration practices, and undertaking activities to demonstrate 'credibility' are potentially important precursors to accessing *tertius iungens* actors (Obstfeld, 2005); those actors who enable and potentially catalyse further interactions and network building. In all the cases, those interactions were invariably face to face, reinforcing the importance of direct engagement (Nonaka and Konno, 1998) and the socialization aspects (Dingler and Enkel, 2016).

Bringing together these insights from the cases, a suggested suite of activities emerges, as depicted in Figure 8-4.

An observation is that the process of forming nascent value networks is not a 'design', but is an active, exploratory and evolutionary process. Innovators cycle through activities as they aim to navigate (the nascent ecosystem), negotiate (a position within it) and nurture (the innovation and their value network). Case evidence supporting the suggested links to the innovation micro-processes is summarised in Table 8-1.

Tsanos et al. (2014) identify that these antecedents are important in building supply chain collaborations. Such actions also build trust (Larson, 1992; Todeva and Knoke, 2005), however this trust appears to be needed beyond simple dyadic relationships, instead requiring that trust to be built within the context of the emerging network or ecosystem, through both action and visibility.

The processes, are thus more complex and nuanced than implied in extent alliance forming literature. The case evidence would point to both 'emergent' and 'engineered' processes (Doz et al., 2000) being adopted. Whilst considerable evidence for an 'engineered process' exists, via options exploration, aligning domain interests and filling structural holes, there is also evidence of 'emergent processes' with a need for similar interests, defining boundaries, and evidence of learning.

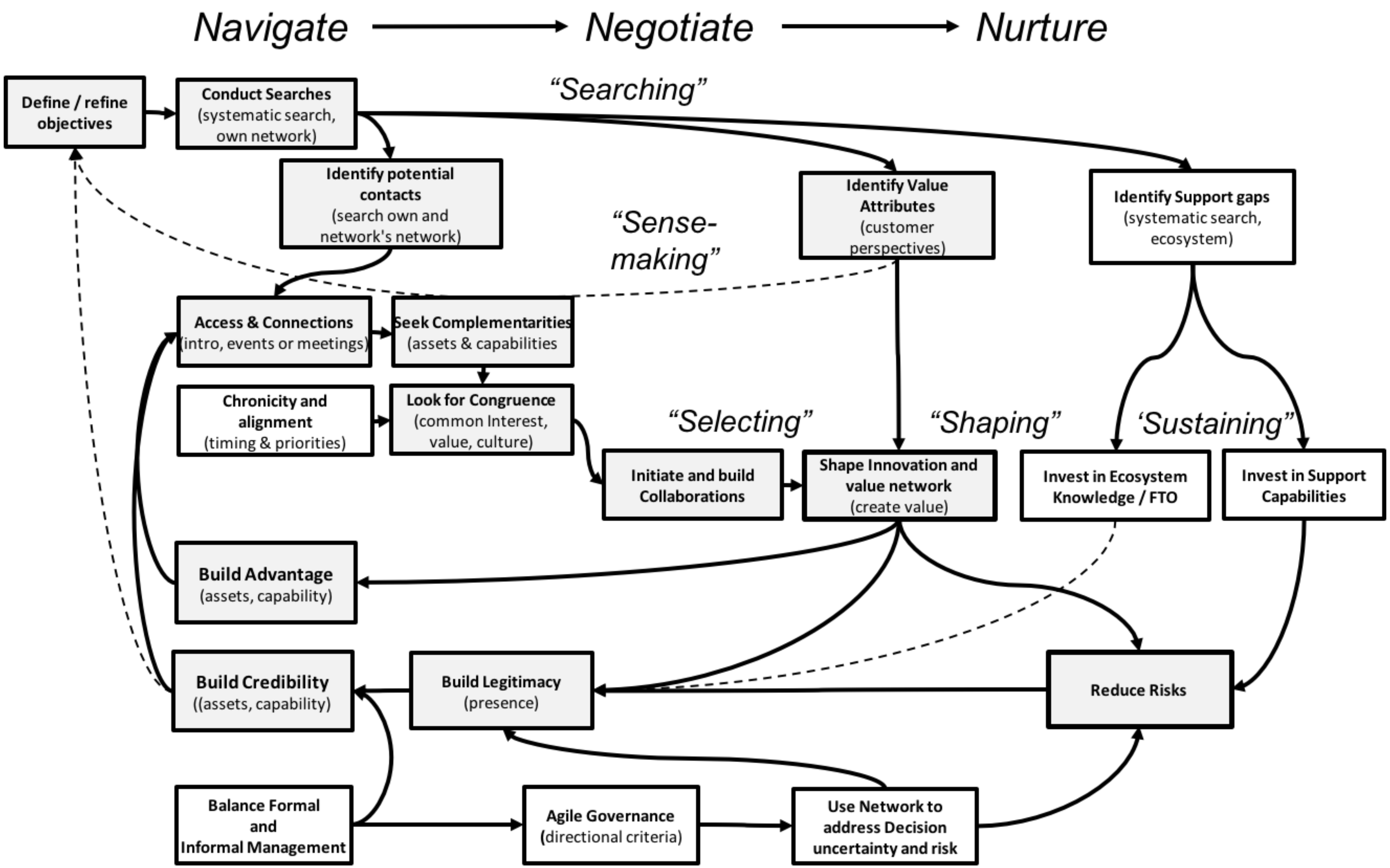

Figure 8-4 Suggested processes for formation of Nascent Value Networks

Table 8-1 Summary case evidence of micro-processes in value network formation

Activity	Example actions	CMTI	DH1	NMD	MLD	DH2
Searching	Exploratory search, beyond normal network	Yes	Yes	Yes	Yes	Partial, Narrow search
Sense-making	Engaging diverse actors to understand value and risks	Yes	Yes, extensive	Yes, extensive	Yes	Limited
Selecting	Directional criteria, use ecosystem to aid	Yes	Yes, Partial	Yes	Yes, Partial	No
Shaping	Invest in innovation, value network and business model	Yes, multiple options	Yes, multiple options	Yes, multiple options	Yes, multiple options	Yes, focused
Sustaining	Invest in building relationships, creating credibility and legitimacy	Yes	Yes	Yes	Yes, Partial	No

These approaches would support that moving into 'uncharted territory', where '*potential partners are neither actors you can easily identify nor are they (once you find them) likely to be keen to engage with you'* (Birkinshaw et al., 2007), requires different network building approaches. However, this research would suggest that alternative paths to those identified by Birkinshaw et al. (2007, p. 81) are available to innovators. None of the five cases attempted to use 'knowledge brokers' or 'independent network-builders' but instead invested and directly engaged themselves, and took advantage of opportunities that arose through those connections. It is suggested that in such networking activities, the act of direct engagement was a precursor to building credibility and trust, and importantly by directly engaging, the innovator can build meaningful domain knowledge and understanding.

The uncertain nature of the environment also makes decision processes challenging, organizations appear more likely to rely on interpretation and broad criteria (Daft and Weick, 1984; Dean Jr and Sharfman, 1996), as part of their 'exploitative' learning process (Kim and Atuahene-Gima, 2010). The evidence that innovators engaged their ecosystem to help in investment decisions has the *internal effect* of reducing risk and the *external effect* of being seen to value the other ecosystem or network actors; this reciprocity being important in building wider trust. So, focusing on value creation alone is insufficient, there is also a need to invest in the value network and the ecosystem itself (Smith, 2013), thus these *relationship specific* *investments* help to *sustain* the innovation, and ecosystem, by making and encouraging network connections (Garriga, 2014).

Higher levels of network integration are considered important indicators of performance (Prajogo and Olhager, 2012). Whilst this may hold for established industries and their supply chains, developing a highly-integrated value network at this phase in the innovation and ecosystem lifecycle was not observed; the one case that attempted something akin to this failed. The evidence suggests that whilst highly integrated networks may be a longer-term goal, there is a need to develop flexible and looser networks first. The reasoning suggested for this is - that innovators first need to build their ecosystem credibility, and to build knowledge and capability, to make better decisions on longer term partners. For an incumbent firm, there are also the challenges of internal acceptance whilst the innovation risks are still high (Tushman and Reilly, 1996), which is addressed later. For the start-up firm, creating highly integrated networks implies a resource commitment and early focus that may increase risk. Considering this in terms of a pathway, knowledge distance and network integration (Figure 8-5) for both incumbent and start-up firms, route C carries higher risk for the reasons explained above. Of the 5 cases, the one failure was effectively attempting the direct route C, the four other cases adopted approaches analogous to route A-B. So, instead of building highly integrated networks it is observed that firms initially move to establish many looser, shorter term relationships, before making a commitment to longer term alliances.

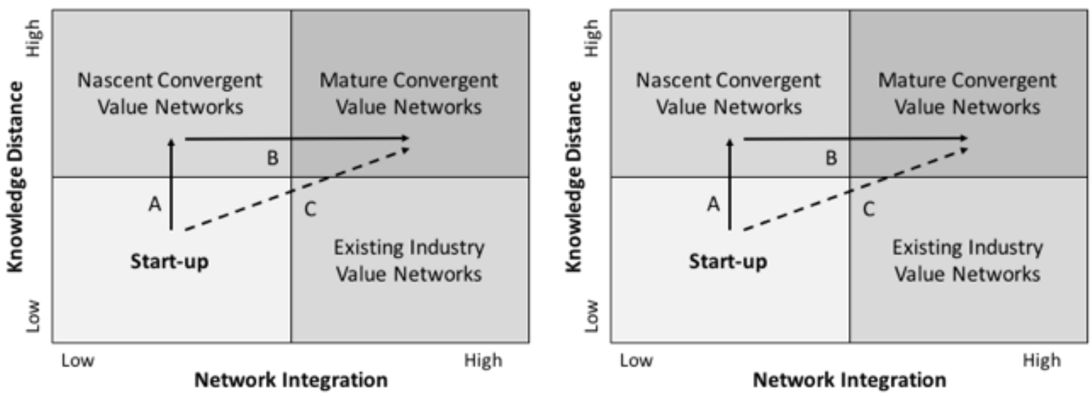

Figure 8-5 Suggested migration paths for start-up and incumbent firms to form integrated value networks

Comparing configuration concepts in mature supply networks (Harrington et al., 2012; Srai and Gregory, 2008), 'emerging' contexts (Harrington and Srai, 2016), and 'nascent' contexts, structure *may* be regarded as the most critical in a mature context and is focused on tier structure and shape, addressing increasing geographical dispersion and integrating mechanisms. With limited structure in an 'emerging' context, partner and process selection (customers and suppliers) and developing longer term relationships (new and existing) may be most critical and include the set-up of new partnering arrangements within emerging clusters of activity at a new location, while leveraging critical elements of pre-existing supply networks that may be well established and relevant to an 'emerging' context. However, in the case of nascent networks it is argued that as early networks are often transitory in nature, *relational aspects* (i.e. building quality external relationships) may be *more critical than traditional criteria* for partner selection.

Table 8-2 Activities underpinning the configuration of nascent value networks

Configuration Elements	***Navigate***	***Negotiate***	***Nurture***
Relationships	Exploratory Searches Sense-make (and sense-giving)	Initiate collaborations (short-term)	Build legitimacy (internally and externally)
Structure	Widen connections and access to knowledge	Seek complementarities	Build credibility (by delivering tangible outcomes or commitments)
Network Dynamics	Continue to search, as new knowledge emerges	Assess chronicity and alignment Look for 'congruence'	Continue to invest in ecosystem relationships
Governance and coordination	Senior sponsorship and agency to support exploration of domain and opportunities	Agile governance direction rather than detail driven Flexible contracts Use network to aid decision making	Build an advantage-seeking position built upon credibility and increasing capability
Support infrastructure	Identify gaps in support network	Invest in support activities	Invest in ecosystem knowledge and freedom to operate
'Product'	Engage potential 'customers' to help with product definition	Identify value attributes in eyes of potential customers	Reduce early risks Shape innovation

The framework (Table 8-2) synthesises the value network configuration elements, identified by Harrington and Srai (2016), with the proposed activity system and identifies the underpinning activities required by innovators in nascent ecosystems to form nascent value networks as they navigate, negotiate and nurture.

8.6 Value Analysis and Business Modelling

A requirement for innovation is to identify and create value (Adner and Kapoor, 2008). As previously identified the complex value system in healthcare makes this task complex. The plethora of potential customers and adoption chains, often specific to a clinical or care pathway, make generalisation impossible. The cases studied were all pre-commercialisation, so business models had not been fully developed. However, some of the challenges in identifying value and the business model emerged during the research.

For example, DH2 failed to find a model that worked across the different stakeholders they engaged. Each time they met potential partners or investors, a different approach was suggested. NMD recognised that the new venture would entail new business models and had developed some options, but decided to defer a decision until they had more clinical data. DH1 undertook a formal design using the business model canvas (Osterwalder et al., 2010), but then subsequently modified it and used multiple business models, depending on the client. This evidence would suggest that far from being the suggested '*design process*', (Osterwalder, 2004; Osterwalder, Pigneur and Smith, 2010; Osterwalder and Pigneur, 2013), the process for convergent innovation is more evolutionary and exploratory. A design process might be appropriate where there is limited uncertainty and high levels of stability. Where this is not the case, then the combination of *navigation* and *negotiation* previously suggested are considered more appropriate.

A challenge facing innovators in this field are the different perceptions of value by different actors. This is not unique to healthcare, but it is particularly complex. As many of the innovations will transform the care pathway, there is also a path-breaking (Karim and Kaul, 2015; Karim and Mitchell, 2000; Sydow et al., 2009) issue in the potential customers' value networks to be addressed. MLD recognised that they needed different business models in different territories and for different applications, so they undertook activities to help develop these which, by way of an example of the challenges, are illustrated in Figure 8-6 and Figure 8-7 below.

	Target 'customer'	Business Model	Development plan	Platform	Competitive advantage
Diagnostic Screening	Primary Care (e.g. GP) or commissioning group Private care	Charge per test (Equipment FOC or nominal)	Regulatory development and application	Multiple	**Simple, short, no expert required, language independent**
Post diagnosis monitoring	Primary or secondary care or commissioning group	Subscription	Peer reviewed Publication based on the trials	Web based (JavaScript)	**Outpatient compatibility**
Full service diagnostic support	Secondary care (e.g. memory clinics and specialists Private care	Charge per test and equipment	Follow up on initial regulatory application	Software and add-on hardware	**Improved sensitivity with AI algorithm**
Home health monitor	Consumer direct or via health technology partners	Subscription or Licensing	Partnership with health monitor providers	Stand alone or add-on to other existing health monitor platform	**Compatibility with different platforms**
Drug discovery and development	Pharmaceutical company	Licensing	Peer reviewed Publication	Basic test plus add-on hardware	**Repeatability with isolating learning effects**

Figure 8-6 Example business models considered by Case MLD (extracted from MLD Investor presentation)

Product	Screening tool	Diagnostic aid
Description	A primary care tool that enables GPs to screen patients for [conditions] in surgery waiting time, so can quickly assess and refer to specialist care if at risk	A tool applied by specialists at the beginning of the diagnosis process working as a compimentory to the existing settings such brain scan, biomarkers, neuropsychological assessment
Stakeholders:		
Who is the user?	Patient in waiting room	Ultimately the Patient in specialist's clinic. However Health Care Professionals (HCP; Secondary Care, GPs) might contract to use the service; via GP Federations / Commissioning Groups
Who is the use decision maker (to use)?	Ultimately GP asks Patient to do test. Supported NHS guidelines for mental health assessment e.g. everyone aged over 55	Specialist
Who is the buy decision maker (to buy or contract)?	Funding Primary Care - via NHS England or CCG	CCG / Trust Memory Clinic
Who pays for it (ie pays MLD)?	Clinic or CCG?	CCG / Trust Memory Clinic
Value Proposition:		
How does this improve outcome for patient? Implications?	comforting worried well-earlier referal and intervention- biggest implication is that some might not want to know due to the stigma attached: "no tretment"	Earlier (pre-symptom) detection equals better patient outcome
How does this simplify or improve pathway for patient? Implications?	Ease, no need for expert, time efficient, can be run outside the GPs visit room	earlier diagnosis equals earlier intervention. Portable so can be patients or care homes. Potentially more sensivity diagnosis.
How does this add value to GP?	Simplifies GP assessment/screening by avoiding doing MMSE etc	n/a
How does this add value to Specialist?	Increases likelihood they will see earlier to intervene. But may increase their case load (at least intitally)	more sensitive, earlier diagnosis earlier intervention better outcome in terms of treatment options. Reduces diagnostic time / cost
How does this add value to funder?	Save GPs time: http://www.nice.org.uk/Media/Default/standards-and-indicators/qof%20indicator%20key%20documents/NM09%20Cost%20statement.pdf	Major cost savings come from not referring health individuals: http://www.cambridgecognition.com/file-uploads/Final_Poster_Housden_Model_UK_primary_care-pp070714-iii.pdf
How does this change patient management pathway? Implications?	It generates a database of patients mental health status at primary care which can be updated regularly	earlier intervention, but care options remain similar
On what basis do they pay MLD?	Fee per test (more preferable but might come to a huge number)/licence base	Contract for service or subscription model?
Impact:		
How does this change overall treatment/care cost/efficiency?	saves cost on false positives and false negatives- earlier referals	reeuced diagnosis time/cost and potential for earlier intervention reducing lifetime costs
What new costs and what cost savings result from adoption? Who else benefits?	Cost: test-Test platform (PC,tablet etc)-nurse time - potentially more referals?-more early treatment cost... Savings: GPs time-less patients involvement in treatment-less false positives-	Cost of test- saving specialists time- replacing other more expensive cognitive tests such as [xxx]
Evidence Required:		
What evidence is needed to convince users?	Safety / user experience data - easy to use	Safety / user experience data - easy to use
What evidence is needed to convince practioners (GP/specialist)?	Clinical trials: comparative study vs cognetive assessment tools applied at primary care e.g. MMSE, Cantab, etc Time savings potential- additional revenues	Clinical trials: comparative study vs cognetive assessment tools applied at primary care e.g. MMSE, Cantab, etc Time savings potential- additional revenues
What evidence is needed to convince payers?	Cost of current referals today vs DMT cost- Improved treatment cost and oucome	Cost of current diagnosis with/out DMT- Improved treatment cost and oucome
Who else needs to be convinced?	Charities / Patient Support Group / Local Specialists /	NICE?
What evidence do they need?	Robust and useful clinical data: sensitivity, specificity, reproducability, accessibility, health economics, contribution.	Earlier diagnosis has a positive impact on overall care

Figure 8-7 Example of value analysis undertaken by case MLD

A sample of the business model options and potential 'customers' for MLD (extracted from their investor 'pitch deck') are illustrated in Figure 8-6. Within one territory (the UK) they have options for seven different customer types using three different appropriation approaches to yield five different business models for essentially the same technology and innovation. This high-level analysis provides some understanding of needs, but a deeper analysis is required to identify the specific value attributes necessary to meet customers' needs and perceptions.

An example of this complexity is further demonstrated by the later analysis undertaken by MLD to try to understand options for the different propositions (Figure 8-7). They identified several and the relevant stakeholders for each, and attempted to identify what constituted value and how this might inform decisions and payment.

These analyses attempt to address some fundamental concepts in value analysis (Allee, 2008, 2000) and understanding what value is (Bowman and Ambrosini, 2000), how it is created, and captured, and the various user or consumers perspectives of value (Priem, 2007). Essentially, this is part of a sense-making process (Weick, 1995), as innovators aim to position the venture and the innovation with potential investors, alliance partners, customers, users and payers. But these engagements result in perspectives on value that are at the levels of the individual, organisation and society, requiring a multi-level perspective (Lepak et al., 2007). A conceptual model of the process enacted by the case innovators and stakeholders is depicted in Figure 8-8.

Here the innovator develops a proposition and, as part of a sense-making process, tests it with stakeholders and potential users, providers and payers. The proposition is assessed in terms of its *potential* to transform outcomes, pathways and economics, its *use value* (Bowman and Ambrosini, 2010), at an individual, organisational and societal level (Lepak et al., 2007). The interactions with stakeholders result in 'exchanges' that translate or transform (Carlile, 2004) the proposition and enable the innovator to assess unrealised or wasted value (Yang et al., 2014), and what else may be required to create or capture value.

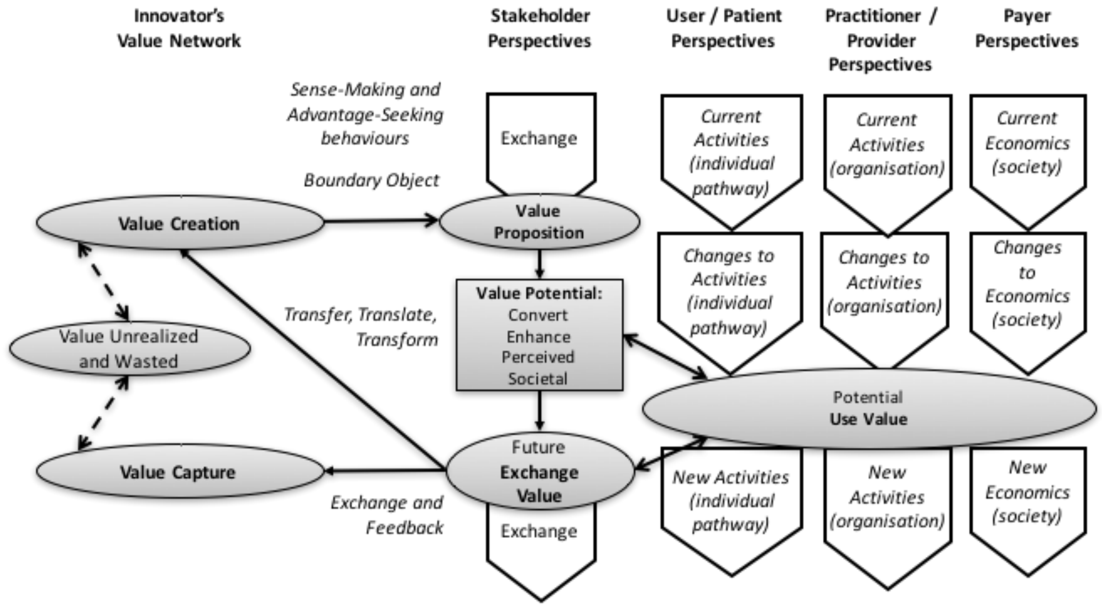

Figure 8-8 Conceptual model of value analysis via exchange

These activities are proposed as part of the '*navigate*' and '*negotiate*' activities, that help with sense-making and advantage-seeking. The outcome of which is a decision to shape the innovation, or put in place mechanisms to sustain it. This would imply that the development of the business model is intimately linked to the innovation process, the formation of the value network and organisational capabilities required. This link and the complex value system into which the innovation is placed, suggest that the business model is more than just 'a model' (Baden-Fuller and Morgan, 2010), or a series of processes, but instead is part of a system.

A business model that is viewed as more systemic supports the argument that business models can be considered as 'value creating systems' (Fuller et al., 2000). So, conceptualising a business model with activity system perspective (Zott and Amit, 2013, 2010) may be more appropriate, or taken further, recognised as a complex system in its own right (Velu, 2016). Given the interconnectedness and the potential for convergent innovations to transform healthcare systems' value networks, with potentially disruptive and path-breaking changes, these could be perceived as '*systemic interventions' or 'systemic innovation*' (Midgley, 2015, 2014, 2000).

It is clear from all the cases that the business models were not 'designed' (Osterwalder et al., 2010) but instead evolved through multiple interactions and engagements with stakeholders in the value system. In that sense, they could be considered 'emergent' (Mintzberg, 1978). But these activities do not take place in a stable (or quasi–stable) environment, the innovation ecosystem, actors and value systems are evolving, adding to the complexity. Conceptually this challenge could be considered to be analogous to an 'adaptive walk in a rugged landscape' (Kauffman and Levin, 1987). There are multiple options available to innovators, potentially with multiple local optima. The innovators aim is to develop a business model that provides advantage over competitors. But, a distinction between the original biological 'rugged' landscape and associated NK models (Kauffman and Levin, 1987; Kauffman and Weinberger, 1989) and the 'performance' landscape (Rivkin and Siggelkow, 2007) in business and innovation ecosystems, is that in the former, the landscape is assumed to be random, whereas the latter involves human agents. Nevertheless, the concept of using the evolving business model as the basis for value exchanges to navigate and then negotiate in a performance landscape provides a potentially useful conceptual model for business modelling and innovation in nascent ecosystems, and one worth further exploration.

As changes in healthcare systems and technology innovations continue to evolve new pathways, new landscapes, new ecosystems and new business models will emerge. Evidence of these changes can be found in drives to move from 'healthcare' (and associated treatment) to 'wellness' (Roco and Bainbridge, 2013) and more sustainable models (Christensen et al., 2009). New models beyond the plethora already identified in this sector (Sabatier et al., 2010) will likely emerge, requiring innovators to undertake more exploratory searches, consider diverse alternative options or develop entirely new ones.

8.7 Leadership and governance

CMTI, DH1 and NMD (incumbent organisations) all employed small dedicated teams supplemented with external resources. These small teams provided an entrepreneurial, start-up like capability. This is unsurprising given the extensive body of literature on entrepreneurial activities (for example Den Ven, 1993; Eckhardt, 2003; García-Morales et al., 2006; Garud and Karnøe, 2003). More interestingly, in all three cases the selected leader not only possessed entrepreneurial attributes expected to develop the innovation, but also had the authority, credibility and confidence (Burgelman, 2002; Rosenbloom, 2000) of the senior leadership, and were able to skilfully navigate the internal organisation and culture. For example, in case NMD, the option to select an external leader, although they possessed superior technical and network knowledge, was considered but rejected in favour of an internal candidate, precisely for their ability to manage the internal organisation and culture, as summarised by NMD1: "*To make this venture a success we need to do two things – make the right scientific calls (and clearly the external candidates were better placed to do this), but we also needed to navigate the internal organisation. And the view was that they would not be able to do that as well*". This points to leaders in convergent innovation not only needing technology entrepreneurship (Garud and Karnøe, 2003; Gavetti and Levinthal, 2000; Teece, 2012), with the requisite intuitive and less analytical approach (Armstrong and Hird, 2009), but also to be culturally skilful agents capable of navigating internal power structures in order to legitimize a potentially disruptive innovation (Lounsbury and Glynn, 2001).

In these three incumbent cases, the ventures had senior leadership support, and were somewhat separated from the rest of the organisation during their formative stages (Gwynne, 1997). The organisations put in place agile governance structures evolving from early informal signoff by a senior leader to a new governance body or board with the internal and external knowledge experts to support decision making. The literature on governance process for innovation or new product development is limited (Baker and Bourne, 2014; Kijkuit and van den Ende, 2007) but has largely focussed on frameworks that balance the need for creativity and control (Peters and Waterman, 1982; Simons, 1994), such as a stage gate (Cooper, 1990). The evidence in this research points to a more nuanced approach, with broad, directional criteria and the use of external actors to help support decision making. Extensions to the stage gate approach, such as its use in open innovation (Gronlund et al., 2010) point to a mix of closed and open innovation criteria being used. However this was not observed and, further, had the suggested model of open innovation criteria been followed (Gronlund et al., 2010, fig. 2), it is unclear whether the ventures would have been progressed.

In all cases, the innovators lacked 'hard data' to support traditional decision criteria, instead they were largely interpretive (Dougherty, 1992), where sense-making (Weick, 1995) and shared understanding are important. A broad range of criteria were considered but interpretation was more qualitative or semi-quantitative; more akin to those suggested for front end innovation (Koen et al., 2001). This in part is thought due to limited codification of information or that information across multiple technological domains somehow needed integrating. The use of external expertise and challenge helps to overcome internal bias and inertia (Nooteboom, 2000), and face-to-face interaction further facilitates interpretation (Daft et al., 1987), but does present a model for governance and decision making under conditions of convergence.

This research indicates that there is a potential gap, as approaches in closed innovation and open innovation do not appear to address the challenges in terms of the implications for governance and decision making that result from convergent or cross-industry innovation.

8.8 Development of Innovation and Organisational Capabilities

This research fundamentally asks the question '*how*' do firms innovate. This question inevitably addresses the subject of routines and capabilities. In this section, an argument will be developed to describe how these routines and capabilities may be developed, and why, which will then be synthesised with the frameworks and approaches developed so far.

In this research three incumbent case firms and two start-ups were studied. One of the supplementary questions arising during the research, in the case of incumbent firms, is - *whether developing something 'convergent' and potentially disruptive also requires doing it differently*?

Innovations themselves can be a source of new organisation capabilities (Greve, 2013), but in engaging with the above question, two underlying puzzles emerge. First, the literature on organizational capabilities has largely embraced a stark dichotomy between sustaining existing organizational capability and developing a new one (di Stefano et al., 2014; Helfat and Peteraf, 2003). Second, reciprocal relationships between managerial agency and organizational capability have mostly escaped scholarly attention (Argote and Greve, 2007; Garud and Gehman, 2012). Instead, the focus has been on how organisational routines determine managerial action and much less on how managers as knowledgeable agents deploy, modify and enact organizational capabilities.

8.8.1 Sustaining 'old' versus developing 'new' organizational routines

The literature on organizational capabilities has always been more comfortable with explaining gradual change (Helfat and Winter, 2011; Nelson and Winter, 1982) than with clarifying emergence of novelty. The intellectual legacy of the evolutionary framework emphasizes habitual and experiential learning (Winter, 2013; Zollo and Winter, 2002) and hence it is assumed organizational capability predominantly changes through selective reactivation or minor modification of past patterns and routines. From this evolutionary perspective, changes to the organizational routines and the actual practice of what managers do and how they get it done (Birkinshaw et al., 2008) are hardly ever large and discontinuous. When examining radical innovation, Kapoor and Klueter (2015) argue that the use of alliances and acquisitions increase the likelihood of incumbents successfully developing disruptive technologies.

This accumulative sustainment of existing organizational capability is then sharply contrasted with situations where firms are confronted with a major external jolt (Henderson and Stern, 2004; Peteraf and Reed, 2007; Rosenbloom, 2000). Bresman (2013) for example suggests that in high velocity environments, groups engaged in radical innovation cannot simply learn from the experience of others. In this context, existent organizational capabilities prove to be mostly inadequate and hence managers at incumbent firms face not only technological and market uncertainties, but also organizational uncertainties of how to develop new ways to innovate.

This dichotomy between sustaining existing organizational capabilities for innovation versus developing entirely new ones leads to two different implications for managers at incumbent companies. They should either replicate (Szulanski, 1996; Winter and Szulanski, 2001) existing organizational capabilities and learn 'as they go', or radically depart from the existing ways of how they innovate.

8.8.2 Managerial agency for changes and internal acceptance

What informs a direction of change and what managers consider when they deploy and modify innovation processes is of importance to understand the role of managerial agency in shaping organizational routines. The extant literature treats the role of managerial agency for change in different ways. Managers with superior cognitive competency are considered capable of sensing entrepreneurial opportunities and these guide any subsequent organizational actions (Gavetti, 2012; Gavetti and Levinthal, 2000; Teece, 2012, 2007). An alternative perspective, that attributes powerful agency to managers, emphasizes leadership and authority (Burgelman, 2002; Rosenbloom, 2000) as instrumental for major changes.

These two perspectives are sharply contrasted with the view that managers at incumbent firms are more likely sources of cognitive inertia (Christensen and Bower, 1995; Tripsas and Gavetti, 2000), which partly explains the failure of incumbent firms to develop a disruptive or discontinuous innovation. Not only are they incapable of changing organizational capabilities, but these deep-rooted organisational routines act as core rigidities (Leonard-Barton, 1992) trapping managers into existent ways of doing things. This suggests that managerial agency within an incumbent firm contains activities of issue-selling to the higher authority (Dutton and Ashford, 1993) and skilful framing of how disruptive innovation may support competitive advantage (Pandza, 2011). Managers are therefore, not only cognitively competent actors, but also culturally skilful agents capable of navigating internal power structures to legitimize a potentially disruptive innovation (Lounsbury and Glynn, 2001).

The evidence from the three incumbent firms supports that they were all capable of making changes and overcoming inertia. Of the three cases, NMD, provided the most compelling evidence and provided sufficient insights to suggest a mechanism by which they created these new capabilities. As has been highlighted earlier, there is a need for innovators to create both credibility and legitimacy in the new field. This is considered a necessary precursor to taking an advantage-seeking position.

Being able to take an *advantage-seeking* position is considered a necessary step in overcoming internal resistance. Simply, if the organisation cannot see potential value in any new venture, and that venture represents a perceived risk, then it will resist. But the perception of the risk is also a critical factor. Doing things that are new, potentially disruptive and less understood are often perceived as riskier (Kahneman and Tversky, 2007), it is therefore suggested that the steps to doing something different or new, should minimise the *perceived* risk.

The findings lead to the proposition that conceptualizing a change in capabilities, requires understanding the structure of this change, identifying drivers that direct managers modifying existing organisational routines and recognizing the role of organizational capability for increasing acceptance of a venture inside an incumbent firm. Figure 8-9 depicts interrelationships between structure of change in organizational capabilities, drivers for this change that predominantly stem from a necessity to build and navigate an emergent innovation ecosystem and an importance to prevent a perceived uncertainty of developing new organizational capabilities to obstruct internal acceptance of a venture.

8.8.3 Structure of Change in Capability for convergent Innovation

The in-depth evidence from the NMD case indicates that a sharp conceptual distinction between existent and new organizational capabilities fails to adequately describe changes that are required when a group in an incumbent firm develops potentially disruptive technology. Likewise, they are not explained by changes in existing organizational capabilities for innovation sustained through experiential learning, as the dynamic capability literature would suggest (di Stefano et al., 2014; Teece, 2012). Nor do these capabilities act as core rigidities (Leonard-Barton, 1992), underpinning cognitive inertia (Tripsas and Gavetti, 2000) and hampering internal acceptance of convergent innovation.

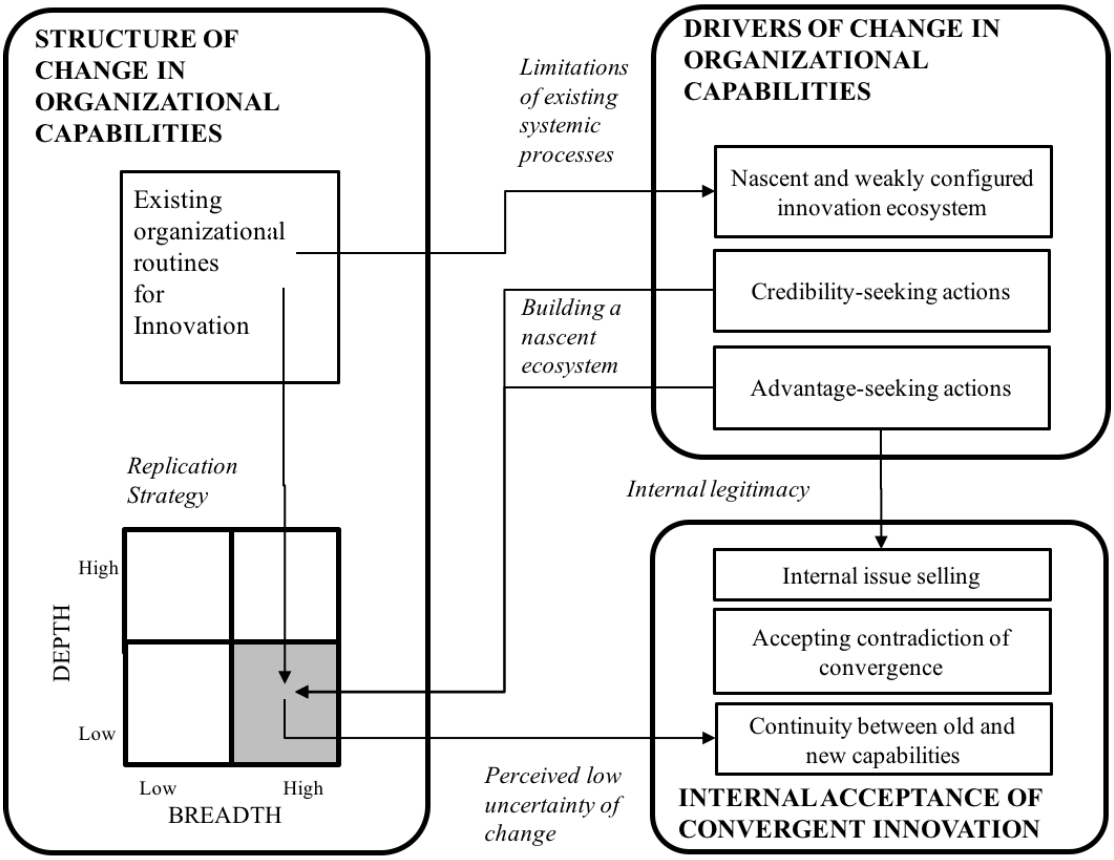

Figure 8-9 Suggested model of capability development

The evidence broadly supports an argument that a convergent innovation and accompanying search in a distant knowledge domain increase the likelihood for existing organizational capabilities to be modified and hence organizational innovation (Birkinshaw et al., 2008) accompanies the development of a convergent technology. This does not suggest existent capabilities become obsolete or radically new ones need to be developed. It is argued that instead of categorizing change in organizational capabilities in terms of its magnitude or 'old versus new' dichotomy, it is more appropriate to explore the structure of this change.

Adopting a systemic perspective on organizational capability (Winter, 2003) enables us to describe the structure of change with the dimensions of breadth and depth. The breadth of change indicates the number of organisational routines that require change to support innovation in a new technological domain. The depth of change denotes a degree to which an organisational routine needs to be altered for supporting the development of a convergent innovation.

The evidence suggests that an incumbent firm makes changes in the underlying organizational capabilities characterized by many constitutive organisational routines being altered (*high breadth of change*), yet the degree of change within these processes will be mostly gradual (*low* *depth of change*). In other words, the development of convergent technology requires relatively incremental changes across many organisational routines. This might be seen as remarkably similar to the exploratory and evolutionary nature of start-up firms capability development as an effectuation process (Berends et al., 2014).

An established firm with a history of technological innovation will possess multiple organisational routines that support innovation capability. They attempt to replicate (Szulanski, 1996) innovation capabilities that proved to be adequate for conducting local searches in a familiar domain (e.g. clinical and biology) for exploring a technologically distant domain (e.g. microelectronics and digital). This initial reliance on replication suggests any accompanying organizational innovation will have continuity with the existing pool of organisational routines and hence depth of change will more likely be low. This insight has an interesting implication for the ambidexterity debate and the dynamic capability concept.

A structurally separated group that explores a distant and convergent domain will, at least initially, deploy the same organizational capabilities for managing innovation in a familiar and core knowledge domain. Most of these organisational routines however, could not simply be sustained through the mechanism of learning by doing and require a significant level of strategic agency to direct necessary modifications to support distant searches for innovation.

8.8.4 Drivers of Change in Organizational Capability

The evidence from the case studies provide insights into what necessitates this change and what considerations inform managers when changing multiple organisational routines.

It has been widely accepted that the development of disruptive innovation requires managing relations in a complex ecosystem (Adner and Kapoor, 2010) and skilfully balancing the need to induce cooperation with advantage-seeking competitive actions (Gnyawali et al., 2006). The extant research has mostly investigated how a disruptor navigates an established ecosystem whose members are highly likely hostile to the innovation (Ansari et al., 2016). What is less often studied is how a resource rich incumbent creates and orchestrates a nascent ecosystem that enables integration of highly dispersed expertise. Such an emergent ecosystem has the characteristic of an organizational field in flux, with undefined industrial borders and an amorphous network of organizations and individuals that are potentially relevant for exploring and developing a convergent and potentially disruptive innovation (Meyer et al., 2005). The cases show that this emergent nature is the most influential factor that necessities multiple modifications in existent capabilities. Each studied incumbent company was clearly in possession of numerous organisational routines for managing relationships in the biomedical ecosystem and managers initially intended to replicate them within the emerging ecosystem. The cases encountered multiple limitations that required changes in organisational routines. It is argued that these changes in organizational capabilities are needed because the organisational routines, which are adequate for navigating an established ecosystem are imperfect for *building* a nascent one. It is suggested that the more nascent and less configured the innovation ecosystem, the higher the need for broad changes in organisational routines that constitute organizational capabilities at an incumbent firm.

The nascent nature of the innovation ecosystem also influences the managerial considerations that guide modifications of the existent processes. To induce cooperation in such an emerging field, they should first legitimize the ecosystem and second, legitimize the firm position within it. It is important to assert that these legitimacy-driven actions and accompanying framing strategies directly impact changes in organisational routines. For example, framing collaboration as 'open' is not sufficient if not accompanied with concrete changes in how a firm manages its IP.

These legitimacy-driven actions appear dominant at the very early stages of creating a nascent innovation ecosystem. When the ecosystem becomes better configured, these actions are quickly accompanied with more assertive advantage-seeking actions that aim to appropriate future value for the innovation.

8.8.5 Structure of Change in Capability and Internal Acceptance

The evidence also infers that strategic actions within the innovation ecosystem and the identified structure of change in organizational capabilities affect the prospect of the convergent venture to be accepted internally.

It is intriguing that in the specific NMD case no significant internal objections, driven by cognitive inertia and dominant logic (Bettis and Prahalad, 1995; Tripsas and Gavetti, 2000) to the innovation initiative, were observed. Similarly, DH1 and CMTI progressed without major objections. Therefore, multiple explanations have been considered. One possibility is that these potentially disruptive technology initiatives are still in their infancy and it is simply too early to expect any serious internal opposition. This explanation, is considered less plausible because the establishment of an ambitious joint venture with a major information technology firm in the case of NMD, and a major investment at CMTI, clearly indicate a serious commitment to an emergent field. The innovation initiative at NMD has a strong champion in a very senior executive also supports the argument of an organizational culture open to efforts that may potentially make existent business obsolete. However, other, potentially more captivating evidence that links internal acceptance with the structure of change in organizational capabilities as well as with advantage-seeking actions within the nascent ecosystem is suggested. Informants from the group leading the NMD innovation initiative agreed that it is important '*not to be seen as any different*' to the other innovation groups. It is acceptable for the group to be *seen* as exploring a *radically* new technology and business model, but it is also important to conduct this exploration by using similar innovation processes as other groups. This inevitably triggers a parallel with Ansari's et al., (2016) assertion that disrupters are well advised to avoid framing themselves as being disrupters. Their example emphasizes the importance of framing for the external audience. This study indicates that being seen *internally* as innovating in a familiar way helps to avoid opposition. What counts is not only internal framing and effective issue-selling, but also the structure of change in organizational capabilities (high breadth, but low depth) that create an internal perception of low uncertainty related to required organizational change.

Therefore, it is proposed that the likelihood for a convergent innovation initiative to receive internal support in an incumbent firm increases if changes in organizational capabilities for innovation are perceived as continuous and consistent, and hence less uncertain. In other words, decision-makers at the incumbent organization will be tolerant to technical and market uncertainty (Danneels, 2002), yet they will be much less willing to accommodate radical changes in underlying capabilities for innovation (uncertainty of how the convergent innovation is done).

Looking to other incumbent firm evidence, DH1 although developing potentially disruptive innovations and using novel processes to engage patients and users, nonetheless used, at least initially, recognisable processes to set up contracts and manage projects and reporting. They modified these, to better suit their needs, but their use of small modifications to established processes, provides further evidence of the proposed mechanism. They also build credibility within the ecosystem and produced tangible outputs, demonstrating their potential value to the incumbent organisation. The third case, CMTI, provides less compelling evidence, in part because those processes were not directly observed to the same degree, but provides some evidence of building credibility and then moving to a position of advantage, without making a step change in 'how' they operated or governed.

Returning to the initial dichotomy identified between old and new organizational capabilities, the development of a convergent technology will almost inevitably require changes in organizational capabilities. The existent organizational capabilities however, do not necessary act as core rigidities that underpin cognitive inertia. They more likely provide a useful initial ingredient for a knowledgeable manager that skilfully balances between necessary modifications across multiple organisational routines and sustaining a perception of continuity between the old and the new ways of doing innovation at an incumbent company.

In studying and identifying this, the challenge of Garud et al. to use "*multi-level, longitudinal perspective, and follow events implicating actors, artifacts, and institutions over time*" (2013, p. 803) is partially addressed. It also responds to the challenge of addressing context and sub-text of agency to identify not only *how*, but also *why*, innovators develop these capabilities.

8.9 Updated Convergent Innovation Framework

Returning to the overall research objectives, and the final objective: towards *the development of a more integrated approach to link the key and relevant aspects of the innovation ecosystem, business model and value network.*

The development of this framework started with the Exploratory Framework, developed during the Phase 1 research and was developed from a combination of induction from ecosystem interviews together with relevant literature and is described in Chapter 5. This was then used as an exploratory tool for the case study research. Findings from each case were mapped against the Framework Factors (see Chapter 6 on Case findings), then cross-case analyses examined the application of the exploratory framework factors across each case.

The proposed and revised *Convergent Innovation Framework* considers three areas: the development and management of relationships in the ecosystem, leadership and management of investments and capabilities, and building value networks, alliances and support.

8.9.1 Development and management of relationships in the ecosystem

Given that convergent innovation ecosystems are invariably nascent, with diffuse and distant actors and knowledge, the development and management of those relationships and the access to knowledge and future partners it may bring is a key activity. The need to orchestrate, or purposefully build and manage relationships has been identified (Dhanasai and Parkhe, 2009), but is comparatively understudied (Still et al., 2014). This research and the suggested framework support the argument that firms employ both tangible (i.e. outputs) and intangible (i.e. relational) mechanisms to build and manage their position within the ecosystem (Ritala et al., 2013). A key step is to build symbiotic relationships (Fransman, 2007), which is challenging in a regime where actors operate at different 'clockspeed' (Fine, 1998) and have different capabilities (Jacobides, 2006). Whilst the ultimate objective for the innovator is to create value (Adner and Kapoor, 2008; Di Gregorio, 2013; Lepak et al., 2007) and then capture or appropriate it (Bowman and Ambrosini, 2000; Lepak et al., 2007), it is suggested in this research that there are precursors or antecedents to being able to do this. These lie in the need to build trust (Gassmann et al., 2010b; Hurmelinna-Laukkanen et al., 2012), and learning, by a combination of activities that demonstrate credibility through visible commitment (e.g. by delivering tangible outcomes or making investments) and legitimacy (e.g., by entering agreements that are seen to be 'fair'). This combination of activities enables innovators to build knowledge, relationships and credibility, which then positions them to take more advantage-seeking actions. The building of learning, trust and ability to take control can be viewed as co-evolving (Inkpen and Currall, 2004).

8.9.2 Leadership and management of investments

The importance of leadership in innovation is well documented, whether that be from a failure to recognise disruptions (Rosenbloom, 2000; Rosenbloom and Christensen, 1994), leading the innovation (Adams et al., 2006), creating the culture (Leonardi, 2011) or providing appropriate governance (Baker and Bourne, 2014).

What appears to be key for convergent innovation is to build a degree of protection (from corporate rejection) early in the venture, at least until there is evidence to support the potential value at an acceptable risk. Unlike established business and new product development, well defined decision criteria appear little used, with innovators relying more on broader criteria and in using external expertise or ecosystem actors to help reduce bias (Dosi, 1997; Garud et al., 2014) and gaps in knowledge (Boschma, 2005). There is a need to build new organisational capabilities, here it is suggested that management agency, using multiple broad but shallow changes to existing capabilities, evolutionary in nature, is likely to yield these and avoid internal conflict. It would also suggest that there is a complex interplay between the components of innovation capability, across governance, process and decision making, with similarities seen in radical innovation (Slater et al., 2014).

The other key consideration is how the complexity of the multiple challenges are managed. There is a need to address integration at multiple levels, but it is also suggested that rather than try to minimise complexity, via approaches like modularity, innovators embrace the complexity (Garud et al., 2013) and use a range of approaches to address it.

8.9.3 Building Value Networks, Alliances and Support

The need to build a value network is key to delivering and capturing value (Dhanasai and Parkhe, 2009; Garcia-Castro and Aguilera, 2015; Hurmelinna-Laukkanen et al., 2012). Other alliances may also be important in building knowledge or creating future opportunities. For a venture to succeed there is a need for a value network to be in place, and there is a need to overcome institutional barriers (Aarikka-Stenroos and Ritala, 2016), and to address the lack of institutional support. In nascent ecosystems these are not well established, therefore innovators need to consider the implications and how to support the building of a viable ecosystem (Rong, 2011). Similarly, the understanding of the venture by potential partners may be poor. This implies that previously identified approaches to partner selection (Emden et al., 2006) and the extent to which there is co-vision, co-design and co-creation (Liu and Rong, 2015) may be limited in nascent ecosystems. This research identifies that it appears to be appropriate to take a more transient approach and use these to build relationships, before moving to a more advantage-seeking position and committing to long-term alliances and more integrated value networks for co-creation.

8.9.4 Conceptual model of convergent innovation

In seeking to integrate the research findings, a single conceptual relational framework is proposed (Figure 8-10). The framework links the innovator organisation via *relationships* (and value exchanges) with the wider ecosystem, customers, collaborators and their value network, through the application of the underpinning processes that enable navigation, negotiation and nurturing of the innovation, business model and value network as the innovator seeks to achieve key objectives to build credibility then advantage by employing incremental, but systemic, changes of existing routines which help maintain internal (organisational) relationships. These capabilities are relational (Dyer and Kale, 2007; Dyer and Singh, 1998), rooted in the organisations ability to build inter-firm capabilities to manage knowledge, alliances and potential value. But given the nature of the innovation, there is also a need to build or maintain intra-firm relationships to avoid inertia or rejection.

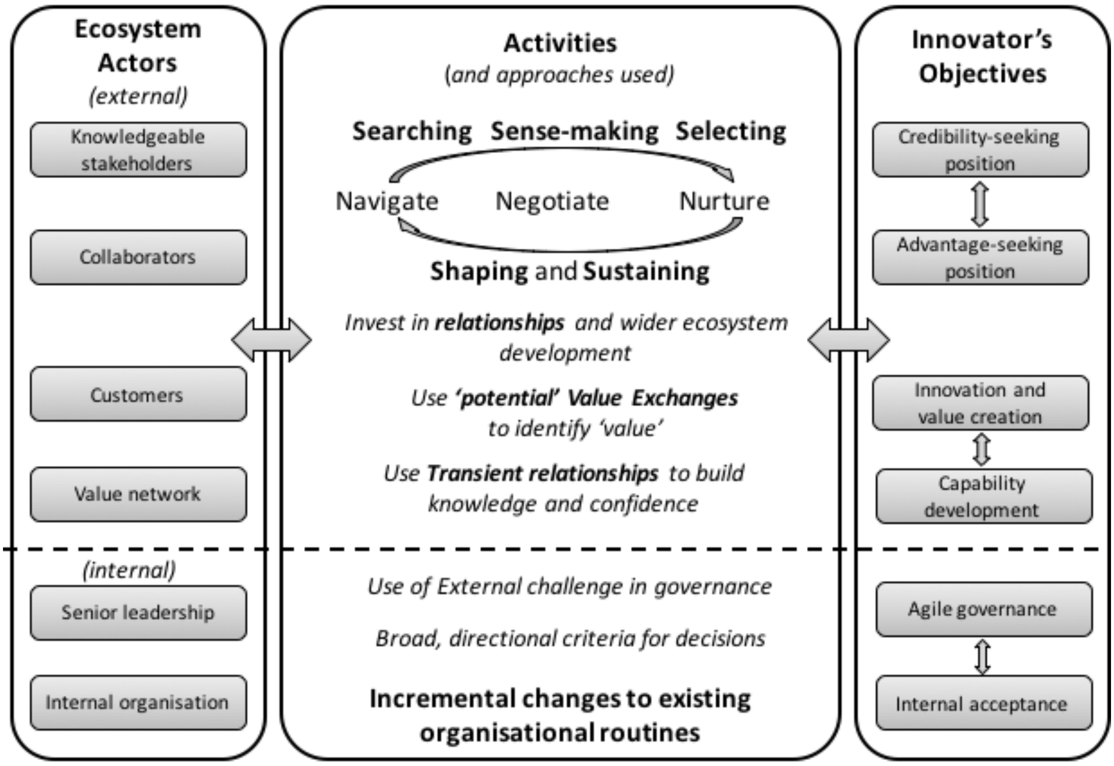

Figure 8-10 Relational Framework for convergent innovation

8.9.5 A Revised Convergent Innovation Framework

The convergent innovation framework, was initially developed by using induction to identify key dimensions from the initial ecosystem interviews (Table 5-2), together with relevant literature and abduction (Table 5-4). This initial framework was then tested using pilot studies, and used as an investigational framework for the case studies. Following the case studies it was reviewed and refined (Figure 7-1). The revised Convergent Innovation Framework (Table 8-3) provides a more systemic approach to explicitly link the activities of developing an understanding of the ecosystem, the value creation and capture activities and the capabilities required to co-evolve the innovation, business model and value network, thus addressing the previously identified gaps in the literature and meeting the research objective. It also provides outline guidance for innovators in this or similar fields, with nascent or emerging ecosystems.

Table 8-3 Revised Convergent Innovation Framework

	Factor (F)	Example Activities and Capabilities
Development and management of ecosystem relationships		
F1	**Ecosystem understanding and relationships within it**	Use active, exploratory and evolutionary searches to identify and understand diverse knowledge and actors. Develop from diffuse knowledge to more codified. Develop both knowledge and relationships through *credibility-seeking* actions in the nascent ecosystem, to enable later *advantage-seeking* actions.
F2	**Customer engagement**	Engage potential customers and users early, and maintain engagement throughout development. Use to address innovation and adoption challenges.
F3	**Business model development and integration**	Use the 'value proposition' as a vehicle to engage and refine the innovation. Identify multiple value perspectives of customers and stakeholders. Refine business model to address pathway challenges. Integrate business model with innovation and value network development.
Leadership and Management of investments		
F4	**Flexible governance**	Active senior management support and engagement in key investment decisions. Provide support to address internal conflicts. Use external expertise to supplement and challenge own knowledge.
F5	**Broad Decision criteria**	Decision criteria are broad and directional, supported by external expertise or ecosystem actor input. Criteria are refined based on knowledge and progress.
F6	**Empowered Project Team**	The core team has leadership, expertise and experience, and balances autonomy, accountability and empowerment within the governance framework
F7	**Business process and capability evolution**	Evolve processes, using *broad but shallow* changes to minimise risk and non-acceptance
F8	**Integrated Risk Management**	Risk management in place to address integration of technological (including patient and user risks), business model risks, value network risks and organisational risks. Balance agency, relational and process foci to analytical and synthesis approaches.
Building Value Networks, Alliances and Support		
F9	**Agile Value Networks**	Use ecosystem relationships to develop flexible and transient nascent value networks before committing to long term alliances.
F10	**Alliances and Support infrastructure**	Innovator invests in helping support (nurture) nascent ecosystem, addressing institutional gaps, and contributes support to maintain viable infrastructure.

8.10 Sensitivity analysis of proposed models

Within the limited research timeframe, it is not practically possible to conduct an empirical 'validation' of the models proposed in this project. Instead a sensitivity analysis was conducted to assess the proposed models to changes in context, and thereby evaluate their potential validity.

This research focuses explicitly on early stages of ecosystem, namely the nascent and emerging phases. Others have described ecosystem evolution in terms of birth, expansion, leadership, and self-renewal (Moore, 1993) or development, growth and maturity (Rong and Shi, 2009). A recent paper identifies four categories of ecosystem, given the emergent properties of the studied ecosystems (Aarikka-Stenroos and Ritala, 2017). From this analysis, 'Category 2' would be the most appropriate for the nascent or emergent phase, with co-evolutionary logic and 'blurry, emergent , non-linear boundaries' (Aarikka-Stenroos and Ritala, 2017). Growth and Expansion is best categorised as 'Category 1' with growth and competition, and Leadership and Maturity addressed by Categories 3 and 4 with stable business exchanges and value co-creation in more service orientated ecosystems. Taking these ecosystem categories and lifecycle phases up to 'maturity', the model components proposed can be analysed in terms of attributes and focus, and in terms of ecosystem roles (Iansiti and Levien, 2004) or entrants (Smith, 2013). The analysis is summarised in Table 8-4.

This analysis would suggest that the proposed models (summarised in Figure 8-10), including the five micro-process (or routines), supporting the innovation activity system and its governance, and the credibility and advantage seeking behaviours remain relevant, but the emphasis or actor focus in each changes as the ecosystem evolves and different categories, in terms of co-evolutionary logic (Aarikka-Stenroos and Ritala, 2017), become dominant. Furthermore, the evolution in actor focus, as the context and lifecycle change reinforce the arguments that in complex systems, such as innovation and business ecosystems, that context is critical and influences actions and behaviours. Suggested behaviours or actor focus are identified for each phase using example literature in in Table 8-4. This research therefore identifies new patterns of behaviour for nascent and emerging ecosystems that could then evolve into more established patterns (as identified in previous literature) as the ecosystem matures and the co-evolutionary logic changes.

Table 8-4 Sensitivity analysis of proposed models

	Ecosystem lifecycle phase (from Moore, and Rong and Shi)		
Components from models developed	**Birth or Development (Nascent and Emerging)**	**Growth or Expansion**	**Leadership or Maturity**
Context	Evolutionary, with blurred boundaries, emergent designs and networks *(Category 2)*	Growth and competition. Schumpeterian destruction, new entrants. *(Category 1)*	Seeking to maintain stability. Codification of knowledge, modulatory, Emergence of dominant design. *(Category 3 and 4)*
Searching	Exploratory – wide, then focussed. Search approach evolves as new knowledge and actors identified.	Exploratory, increasing systematic as knowledge is codified and risk / opportunity factors identified	Systematic, as knowledge codified and dominant designs established (Suarez and Utterback, 1995)
Sense-making	Focussed on translation and transforming (Carlile, 2004)	Focussed on translation and transfer (Carlile, 2004)	Largely focussed on transfer, as knowledge is well codified (Carlile, 2004)
Selecting	Broad, directional criteria	Criteria more focussed, specific criteria being established (Cooper, 2008)	Defined decision criteria (Cooper, 2008)
Shaping	Challenging as value perception and customers not established. Essentially path creation focussed. (Garud et al., 2010; Sarasvathy, 2011)	Effectuation and path creation (Garud et al., 2010; Sarasvathy, 2011). Emergence of path dependency (Dosi, 1982).	Largely path dependent (Dosi, 1982)
Sustaining	Need to address institutional and ecosystem support gaps	Institutional gaps are largely addressed, focus moves to competitive networks (Nelson, 2008)	Moves to focus on efficiency and on ecosystem renewal (Anggraeni et al., 2007)
Credibility-seeking and Advantage-seeking actions	Actors largely engaged in credibility-seeking actions, before moving to advantage-seeking actions.	New entrants must address need for credibility. Increasing dominant actors seek to reinforce advantage position	For established actors, credibility and advantage already exists, for new entrants need to address risks of entering ecosystem (Smith, 2013)
Governance	Focus on direction, value creation and managing risk. Agile governance, broad criteria and external expertise	Focus on building a portfolio of innovations. Increasingly codified criteria and internal expertise.	Focus on portfolio and innovation productivity. Internal expertise. Established criteria
Actor Roles	Heterogeneous roles as actors develop propositions, credibility and advantage	Emergence of dominators, niche players and commodity actors (Iansiti and Levien, 2004)	Emergence of Dominant or Keystone role (Iansiti and Levien, 2004)

9 Conclusions

9.1 Introduction

This study has examined *how* organisations innovate to develop new healthcare and medical technology products under conditions of convergence with partners from different industries. It is specifically focussed on early innovation, where the ecosystem is nascent. This topic is increasingly important in practice, as innovation increasingly takes place in more diffuse and complex environments (Enkel and Gassmann, 2010; Hacklin and Wallin, 2013). Despite this there has been limited research of 'how' such innovation is undertaken (Garud et al., 2013)

The key objective of this study was to identify how firms develop convergent technology in these emergent healthcare technology ecosystems, with an emphasis on the organisational routines (Becker, 2004; Nelson and Winter, 1982) underpinning value creation and value capture activities (Bowman and Ambrosini, 2010) and the capabilities required.

9.2 Summary of main conclusions

The convergent or cross industry innovation creates increased complexity and uncertainty, but also results in the formation of new ecosystems. These nascent ecosystems provide the context and environment in which innovators must strive. The focus of this research is to understand: "*How do organisations innovate in complex, highly dynamic convergent and emergent healthcare ecosystems?*"

The key findings that emerge from the case research are:

- The development of the innovation, business model and value network are underpinned by *five interrelated* **micro-processes** (as pre-cursors to organisational routines) that involving ***searching, sense-making, selecting, shaping and sustaining***. These five processes operate in patterns, but are **non-deterministic** to enable an organisation to ***navigate*** (the nascent ecosystem), ***negotiate*** (a position within it) and ***nurture*** (both the innovation and ecosystem).
- The cases suggest that an initial objective for an innovator organisation is to seek legitimacy and a ***credibility-seeking position*** in the ecosystem as a precursor to moving to an ***advantage-seeking position***.
- In nascent ecosystems with distant, diffuse knowledge and actors, the cases suggest that ***relational capabilities*** are critical to access both new knowledge and new partners.

- Case studies suggest that the ***development of new capabilities*** is largely from **broad** (wide ranging) but **incrementa**l (shallow) **changes** to organisational routines, as these create the perception of lower risk and ***enhance internal acceptance***.

A conceptual model integrating these components, providing a link from the ecosystem, via drivers to activities and processes (organisational routines) is depicted in Figure 9-1.

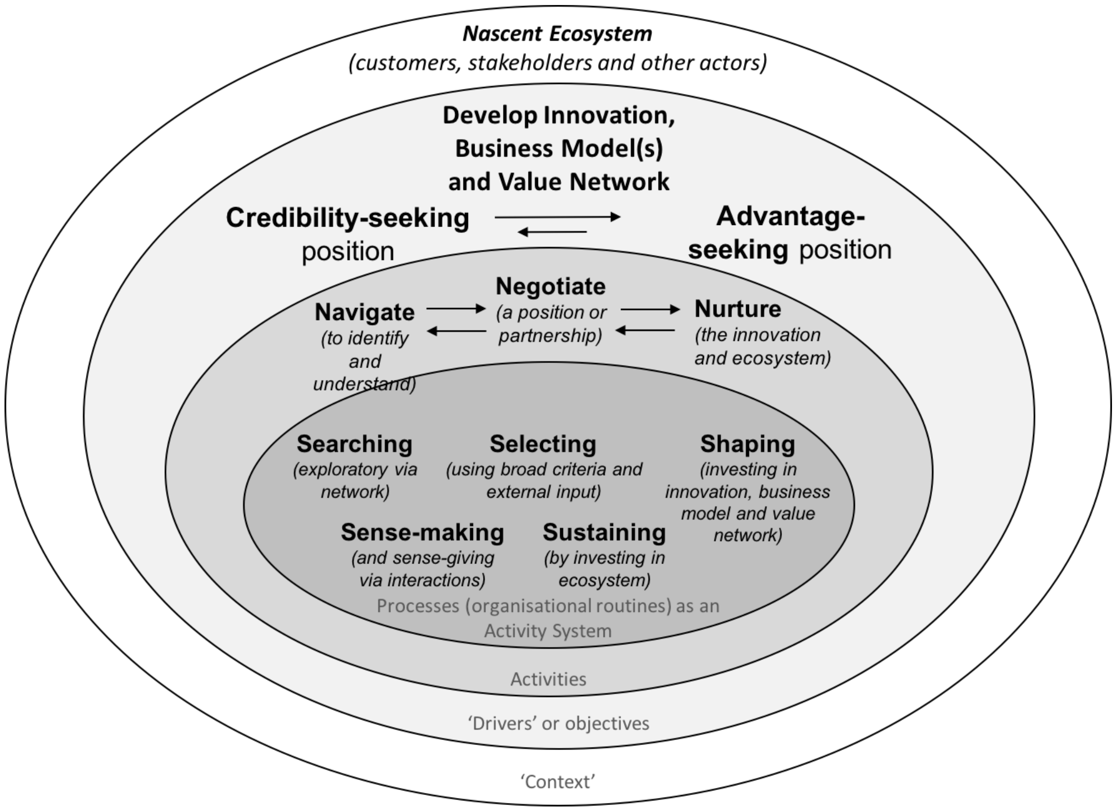

Figure 9-1 Model for convergent innovation in nascent ecosystems

9.3 Key Insights

Several key insights, from the ecosystem interviews and case findings, are summarised below.

An early requirement in convergent innovation and nascent ecosystem is access to new knowledge (Enkel and Heil, 2014b; Hacklin and Wallin, 2013) requiring a 'creative search' (Pandza and Thorpe, 2009). However, rather than using structured or systematic searches, the case evidence points to the use of more exploratory searches (Billinger and Schumacher, 2014), in conjunction with the development of relationships with ecosystem actors. *Managing and building relations* in a nascent ecosystem are identified as a critical step for innovators. The case evidence suggests that it provides the primary vehicle to access dispersed and distant knowledge, and facilitate sense-making and sense-giving (Pandza and Thorpe, 2009; Weick,

1995) and a mechanism to develop the innovation, business model and nascent value networks. This insight supports recent research identifying the importance of direct engagement (Nonaka and Konno, 1998) and 'socialisation effects' (Dingler and Enkel, 2016) in cross industry innovation. These relationally focussed activities aim to address two key drivers, first to achieve *credibility* (i.e. to legitimise your presence in the field as potential collaborator). The cases identify that even large and established firms need to address this as they undertake convergent innovation. In effect they are moving into 'uncharted territory' where 'potential partners are neither actors you can easily identify nor are they (once you find them) likely to be keen to engage with you' (Birkinshaw et al., 2007), and so requires different network building approaches. Once credibility is established, the innovator can then move to *advantage-seeking* actions, implicit in innovation (Adner and Kapoor, 2010; Tidd and Bessant, 2013) and entrepreneurialism (Sarasvathy and Dew, 2013).

These activities are underpinned by a set of micro-processes that are used to undertake exploratory *searching*, provide *sense-making* (and sense-giving), to inform decisions by *selecting* thus *shaping* and *sustaining* the innovation, the value network and ecosystem. The identified micro-processes provide a plausible explanation of underpinning organisational routines (Nelson and Winter, 1982) and a foundation for a *relational approach* (Dyer and Kale, 2007; Dyer and Singh, 1998) to innovation. Together these routines form a *non-deterministic* activity system that enable an innovator to *navigate* (the ecosystem), *negotiate* (a position within it) and *nurture* (the innovation and ecosystem).

There is limited literature on the formation of nascent and emerging value networks (Sebastiao and Golicic, 2008). Traditional approaches to value network partner selection do not appear appropriate, instead a more transient and relational approaches are suggested from the research cases during the nascent phase. Diversity in innovation alliances is recognized as important (for example Nieto & Santamaria 2007), in many of the cases the innovators found that later collaborators were often not those they had engaged early on and so building flexibility into the collaboration practices, and undertaking activities to demonstrate 'credibility' are potentially important precursors to accessing *tertius iungens* actors (Obstfeld, 2005); those actors who enable and potentially catalyse further interactions and network building.

Innovation requires organisations to develop new capabilities (Helfat et al., 2007; David J Teece, 2010; Teece et al., 1997; Tidd and Bessant, 2013). The case evidence suggests that developing capabilities for a convergent innovation requires mostly incremental changes (low depth of change) across many organisational routines (high breadth of change), which create an impression of low uncertainty of organizational change and thus increase the internal acceptance.

The findings support the argument that innovators require a more 'systemic' view of innovation (Garud et al., 2013; Midgley and Lindhult, 2017) and governance approaches. The nascent nature of the field means that investment decisions are hard to assess using specific criteria, to overcome this there is evidence that innovators actively use their ecosystem relationships (for example with stakeholders and external experts as investment board members) and to help understanding, avoid bias and reduce risk. The active but evolutionary approaches identified above suggest analogies to an adaptive walk (Kauffman and Levin, 1987) in a rugged (performance) landscape (Siggelkow and Levinthal, 2003) to evolve the innovation.

The research findings are summarised in a convergent innovation framework with identified factors to manage ecosystem relationships, lead and manage the capability development, and to build value networks, alliances and support.

9.4 Review of objectives and methodology

The research set out to address the question: "*How do organisations innovate in complex, highly dynamic convergent and emergent healthcare ecosystems?*" The rationale for using a two-phase research methodology was that as the innovation ecosystem was nascent, an initial phase was needed to understand that ecosystem, to ensure the research objectives were valid, to provide *context* for the case enquiry.

9.4.1 Research objectives

The early research identified the need to develop a better understanding of the context in which convergent innovation was taking place. This led to the first objective to *develop an ecosystem 'research approach' to improve understanding of systems-based forms of organising, providing a context for later research*. As part of the preliminary research a framework was developed and used to analyse the ecosystem and individual cases.

The key research objective, in direct response to the main research question was to *identify how firms develop convergent innovations in nascent ecosystems*, with a focus in this research on innovation in healthcare technologies. The core of the case research and the resulting models and frameworks directly respond to this objective. This in part also to make a contribution to gaps identified by Garud et al. (2013) by undertaking a more contemporaneous research of innovation processes.

The final objective was to identify more systemic approaches to innovation that embrace the inherent complexity. This objective has in part been met by the development of the activity system model and convergent innovation framework, as these aim to integrate activities in innovation. There is however thought to be scope to further develop the integration concept.

The key objectives are therefore considered to have been met. The following section reviews specific methodological implications.

9.4.2 Research methodology

9.4.2.1 Development of an ecosystem 'research' approach and framework

The importance of context in understanding complex systems is well reported (Pawson and Tilley, 1997; Roberts, 2014; Sayer, 1992). There was a need to establish ecosystem boundaries and describe the key phenomena that would potentially influence all cases. An early review of both ecosystem and value network literature established that there was no prevailing or accepted methodology for this. Further investigation identified a plethora of approaches with implicit methodological assumptions. Given the lack of understanding of the ecosystem to be investigated, it was determined that a more robust approach was required. This formed the first research objective. Consequently, the PBSRDC approach was developed by combining systems theory and related methodologies, as described in Chapter 4. This framework was used as part of the overall ecosystem investigation and for each case. The framework identifies three key considerations (*conceptual, physical* and *temporal*) and the implications in terms of theoretical consideration, method of inquiry and typical research questions.

The framework was applied to the initial ecosystem investigation and this increased confidence that the proposed approach provides a pragmatic method for ecosystem study. Whilst the approach and framework developed is intended to be generic, it has only been applied in limited examples, and so would benefit from wider application and testing to help refine the methodology.

9.4.3 Case Research Approach

Recognising that the aim was to understand innovation processes and practices in an emerging field, obtaining contemporaneous data via longitudinal studies was deemed important (Garud et al., 2013). The longitudinal case studies, although limited in number, provide in-depth and contemporaneous data, with evidence captured in near real-time. This approach also reduced the risks of post-event filtering and recall failures (Flick, 2009) and enabled follow-up of specific themes in subsequent interviews and observations (Easton, 2010), thus providing more in-depth insights into observed actions and decisions. The mix of incumbent firms and start-ups exhibiting similar approaches and mechanisms increases confidence in the findings. As well as seeking direct case evidence, context was provided by obtaining data from the wider ecosystem. This context is crucial to the critical realist approach adopted for these case studies (Easton, 2010; Vincent and Wapshott, 2014). As one of the five longitudinal cases resulted in company failure, it was possible to explore differences between this case and others to support arguments for plausible causation mechanisms.

9.4.4 Research reliability and validity

Despite the focussing on exploratory studies in a diffuse and evolving environment, the methodology was designed to provide reliability, validity and rigour (Gibbert et al., 2008; Gibbert and Ruigrok, 2010).

To build internal validity, the research framework (e.g. exploratory framework and case protocol) was derived (abducted) from a combination of interview data and literature. The analysis procedures used accepted literature sources and recognised research methodologies, such as the Gioia method (2012) (to ensure that the ecosystem was defined as close as possible to the words and intent of the interviewees) and in later case analyses using the ECPO approach, which was derived from Sayer (1992), Danermark et al. (2002) and Easton (2010).

More broadly, this research has been reviewed against six criteria identified to judge realist research (Healy and Perry, 2000). Largely, they follow the expectations identified by Yin (2014) for case research, but deviate to meet the requirements for critical realist research, where epistemological and ontological differences occur. These criteria are summarised in Table 9-1, along with example literature sources for each criterion and a summary of the evidence or approach from this research to support that these criteria being met.

Table 9-1 Summary of validity and reliability considerations for this research

Criteria	Example Sources	Research Examples
Ontology - recognise research as ''world three'	(Magee, 1985)	Research philosophy and methods are rooted in realism (Chapter 4)
Contingent validity - Causal mechanisms influenced by context	(Pawson and Tilley, 1997)	Methods applied determine causation by considering context and tendencies using ECPO process (Figure 4-12), detailed in Appendix A5.
Multiple perspectives are applied	(Danermark et al., 2002)	Research used sources from multiple interview sources, documentation and observations to provide multiple perspectives.
Methodological Trustworthiness	(Healy and Perry, 2000)	Research database in secure Dropbox environment, analysis using NVivo and use of quotations
Analytic generalisation	(Yin, 2014)	No claim is made as to wider generalisation, as this research can be considered as exploratory and theory building.
Construct validity	(Gibbert et al., 2008; Yin, 2014)	Use of original interviews and observations, data triangulation, and reviews with key informants. Documented approach for data collection and analysis.

9.4.5 Limitations

There are several limitations to this research. First, it is restricted to convergent innovation in healthcare technologies. This limits the generalisability of any findings. Secondly, and possibly foremost, is that the number of cases is small, with only five, limited by the practicality of access to firms willing and able to permit contemporaneous and longitudinal studies of their key innovations. However, the limited number of cases is countered by having in-depth and diverse sources. There is also substantial evidence from multiple sources, which increase confidence. Whilst the cases are longitudinal, they are limited to around 15-24 months in duration and no definitive statement on the success of the innovations can be made. However, each case included at least one major 'inflection point' (e.g., a major investment decision, go/no go milestone, formation of new organisation or structure) that provides an indicator of expected success. Given that no outcome for each innovation project was observed, this research cannot determine explicit factors for success, only that certain factors appear to create opportunities, create capabilities and avoid limitations.

Of the five cases, four were ongoing at the end of the research period. One firm failed (and closed), but given the nature of the research, this is an important observation. Because of this failure, the number of interviews conducted for this case is less than intended, however two factors mitigate this: one was the ability to undertake a 'post mortem' interview that helped identify some of the reasons for failure, secondly, the interviews were supplemented by nine documents which help to corroborate findings. Understanding failure is relevant and by identifying differences in patterns of actions in 'successful' and 'failing' firms provides additional evidence to support the suggested causal mechanisms.

A further limitation of this research is that it is qualitative only. Given the nascence of the field, with limited cases and data available, this was deemed the only viable approach. As such, no claims are made for wider generalisability. This research is fundamentally exploratory and theory building, not theory testing. Given the nature of the findings to date and importance of the field and phenomena, it is hoped that subsequent studies (with combination of qualitative and quantitative approaches) can be developed to test the models and frameworks suggested.

The research philosophy employed – critical realism – provided a useful approach to unearth mechanisms in a complex and evolving environment where context is important. The analytical retroduction process is essentially creative, and whilst attempts were made to identify other plausible mechanisms and eliminate these, it is not possible to say with certainty this was comprehensive and that some mechanism was not overlooked. One further limitation of the critical realist approach employed is the difficulty in conducting the analyses. Tools such as NVivo employed here, make qualitative analysis and coding simpler, but the multi-perspective approach required to conduct the ECPO analysis could not be undertaken in NVivo and required large amounts of data to be transferred to Microsoft Excel for analysis. This imposed some constraints on the types of analysis and linkages that could be assessed.

In summary, causal mechanisms have been identified by developing plausible explanations and by the identification and elimination of alternatives. Future research might attempt to conduct a broader comparative analysis of the identified causal mechanisms to highlight those which offer the strongest and most robust explanatory power (Hodgson, 2004; Sayer, 1992). This would entail using a wider data set or seeking to assess the mechanisms in other domains of convergent innovation.

9.5 Implications and contribution to theory

This research was undertaken primarily as a contribution to the innovation management agenda. It focuses specifically on 'convergence' or 'cross-industry' innovation. From an empirical perspective, it addresses convergence in healthcare and medical technologies, which has had little prior research, and as such addresses a gap in the field. It also aims to address a specific challenge in innovation research that of understanding 'how' by identifying the underlying processes (Garud et al., 2013).

The first contribution from this research, focussed on the field of convergent or cross industry innovation is a Convergent Innovation Framework. The framework identifies key factors identified as required in convergent innovation. It extends the work on convergence of Rikkiev and Makinen (2013), on cross industry innovation by Enkel (for example Dingler and Enkel, 2016; Enkel and Gassmann, 2010; Enkel and Heil, 2014a, 2014b; Heil and Enkel, 2015) and also Adner (2008; 2010) by taking an innovation ecosystem perspective and adopting a more relational approach (Dyer and Kale, 2007).

Specifically addressing a mechanism for the innovation, five non-deterministic micro-processes (5S) are proposed to cover *searching, sense-making, selecting, shaping and sustaining*. Evidence was found for the existence of these processes and mechanisms in case research in both small and large firms and in the incubator case. These 5S's appear to play a key role in value creation and provide a simple explanation of the underpinning mechanism and routines for co-evolution within a nascent ecosystem. It is further suggested that these micro-processes form the foundations of *activity systems* (Siggelkow and Porter, 2008) to *navigate, negotiate* and *nurture* the innovation, business model and value network, with early activities to build a *credibility-seeking* position, followed by later *advantage-seeking* actions. These are *relational capabilities* (Dyer and Kale, 2007; Dyer and Singh, 1998) are considered to be important precursors for developing business models, value networks and organisational capabilities. In line with the call from Garud et al. (2013), this research embraces the concept that innovation requires innovators to embrace the complexity, rather than try to manage it. The complexity of convergent innovation requires innovators to integrate diverse knowledge, integrate technical systems, business models, value networks and organisations. An approach to this integration is proposed in the relational model developed for convergent innovation. Thus, this research contributes to innovation and organisational capabilities agendas.

The organisational challenges presented by undertaking convergent and potentially disruptive innovation require that organisations have capabilities that are unlikely to be present in the existing or start-up organisation (Birkinshaw et al., 2016; Rosenbloom, 2000; Teece, 2012). There is a need to build new capabilities, and the extant literature suggests that these are developed or acquired by employing dynamic capabilities (Helfat et al., 2007; Teece et al., 1997) or by exhibiting organisational ambidexterity (Raisch and Birkinshaw, 2008; Tushman and O'Reilly, 2011). In this research, three incumbent case firms and two start-ups were studied. The existent organizational capabilities do not however necessarily act as core rigidities. They are more likely a useful initial ingredient for a knowledgeable manager that skilfully balances between necessary modifications across multiple organisational routines and sustaining a perception of continuity between the old and the new ways of doing innovation at an incumbent company. By adopting an approach using systemic, but incremental changes, there is a perception of "*familiarity*", that reduces the risk of inertia or rejection by the organisation and so increases the likelihood of internal acceptance. The case evidence, thus, suggests a more nuanced explanation for building organisational capabilities, as a contribution to the dynamic capabilities field (Helfat et al., 2007; Teece, 2007; Teece et al., 1997).

The business model literature largely focuses on the model itself or on archetypes, but the evolutionary nature of the business model and the role of business modelling are increasingly important in the research agenda. It is suggested that contrary to approaches like those of Osterwalder (2010), the business model is not a 'design', but evolves (Baden-Fuller and Mangematin, 2015a, 2013). In developing a business model there is intent, but there is also emergence. This is analogous to Mintzberg's (1978) patterns in strategy formation. The contribution to business model literature is that the business model, or more strictly the value proposition, is not just a linking mechanism between ecosystem and value network (Baden-Fuller and Mangematin, 2015a), but also acts in a dynamic way as a 'boundary object' (Carlile, 2004; Leigh Star, 2010; Leigh Star and Griesemer, 1989). This provides a mechanism to explore and evolve the innovation through 'value exchanges' (Bowman and Ambrosini, 2010, 2000) as the innovator takes 'an adaptive walk' (Kauffman and Levin, 1987), developing the potential value proposition with multiple stakeholders in the evolving ecosystem. These exchanges provide the basis for '*business modelling*' and make a contribution to the business model agenda, and in part addressing the limited research in the field of business *modelling* (Baden-Fuller and Mangematin, 2015a).

Although limited to a few cases, taking a contemporaneous and longitudinal case approach addresses an identified gap in the literature on '*how*' organizations develop value networks in this context (Harrington and Srai, 2016). A model for value network formation is proposed, using multiple transient partnerships to build knowledge and capabilities before selecting a longer-term partner. This approach underpinned by the navigate, negotiate and nurture activities is aligned to network configuration principles (Harrington and Srai, 2016; Srai et al., 2014), thus contributing to the value network literature.

Finally, despite the significant interest in business ecosystems in the current literature, there are limited systems-based approaches to ecosystem investigation (Oh et al., 2016; Ritala and Almpanopoulou, 2017). An approach for studying ecosystems, consistent with systems thinking and theory has been developed and initially tested. The PBSRDC methodology provides a step forward in developing a systems-theory consistent approach that addresses the need for taking different perspectives, making an explicit boundary definition, defining multi-level structures and relationships and understanding both dynamics and co-evolution. As such, it contributes to systems-forms of organisation research methodology and, specifically, the ecosystems literature.

9.6 Implications and contribution to practice

This research suggests new approaches to innovation management in a complex health care setting.

From a practice perspective, the research provides mechanisms for building relational capabilities considered critical to innovation delivery. In nascent ecosystems and convergent innovation, the ability to search and sense-make is key. Understanding the nascent and emerging ecosystem is vital to access knowledge, identify risks and identify potential partners. The importance of engaging diverse stakeholders early in the venture is emphasised. Searches are exploratory, but need to be directed and active. Using the 'network of your network' and snowballing appear to be effective approaches. Given the knowledge ambiguity, face-to-face interactions are preferred. But to access knowledge, innovators may need to selectively reveal to build credibility and legitimacy, especially if the field is distinct from their current business. Building trusting relationships is therefore, critical. Later, approaches such as crowdsourcing may be appropriate as knowledge is codified and the innovator has established a position of credibility, but undertaking such activities early is likely to be unfruitful and potentially wasteful. The need to build *credibility* in the ecosystem appears paramount, in the cases, even large incumbent organisations struggled to attract interest or engagement until they had demonstrated via actions their intent and were seen as legitimate, trustworthy and credible by other stakeholders. Here, innovators need to invest in actions that not only progress their innovation, but in those actions that help shape and sustain the ecosystem itself, thus providing a viable and diverse cluster of potential relationships, partners and a supporting infrastructure. These steps are precursors to moving to an *advantage-seeking* position, which enables the innovator to take more exploitative actions.

An approach to building nascent value networks is suggested that requires multiple engagements with diverse stakeholders to create credibility and visibility; necessary to form alliances. Whilst these relationships may be transient, they provide innovators with an opportunity to shape outcomes and their value network. The insights provide potentially important areas for innovators to focus on in terms of approaches to identify collaborators and looking for congruence beyond just technical capabilities. Building strong relationships too early may be risky. *Relational* considerations are potentially more important in in partner selection for nascent value network formation.

Relationships in the wider ecosystem also help in supporting key decisions, either to help identify the right 'problem' or the criteria for selection. Innovators engage their ecosystem in key decisions, for example by employing them as external input in governance boards or advisory teams, which has the by-product of helping further build trust and legitimacy.

With the inherent complexity and uncertainty in convergent innovation, it is unlikely that a business model can be 'designed'. Innovators should therefore look to use the ecosystem actors and a series of potential 'value exchanges' to evolve the design and business model. If the market and ecosystem are not well defined, any 'design' is likely flawed, so experimentation and evolution are critical.

The internal organisational support for the new venture is also influenced by how the innovation is managed: doing something different (i.e. developing a convergent technology) is fine, provided how this is done is not *seen* as too different (and therefore perceived as riskier). The findings have direct relevance for managers in incumbent firms. It is suggested that deploying existing organisational routines is an appropriate starting point for managing innovation in a distant domain, but managers will need to implement numerous incremental changes across a wide range of organisational routines. Although these changes will not be perceived as radical, the very breadth of modifications indicates a significant managerial challenge. The internal organizational support for the new and potentially disruptive innovation is also influenced by how the uncertainty of any accompanying change in organizational routines is perceived by decision-makers and other groups involved in innovation processes. Doing something different (i.e. developing a convergent technology) may not give a license to do it in a different way. Managers leading a convergent and potentially disruptive innovation should avoid "being seen as" acting radically different and this requires skilful navigation of internal interests and framing of how the innovation is done.

9.7 Impact and dissemination

During this research, several opportunities arose to disseminate part of the findings to organisations and institutions and thus to achieve a degree of impact. Towards the later stages of this research several, further opportunities arose to provide input to innovator firms, including a few of the cases.

Other examples of research dissemination and potential impact include:

- Presentation of convergent innovation and ecosystem challenges to Stevenage Bioscience Catalyst, which was used to help inform their future strategy and investment (January 2016)
- Presentation of convergent innovation and implications for innovators and adoption, provided to Health Enterprise East (April 2016), to provide input to support for entrepreneurs and innovators
- Presentation to researchers and leaders at the Research Centre for Pharmaceutical Engineering (RCPE), TU Graz (May 2017).

9.8 Concluding remarks and areas for future work

This research, for practical reasons, was limited to convergent innovation in health care in the UK. As activities are context sensitive, further research studying the phenomena in a different context, or geography (e.g. USA) would be a logical extension. As well as understanding the implications of a different context, such a study would help the generalizability of the findings.

A further extension would be to consider how convergent innovation is undertaken in different contexts, including those in different convergence domains with nascent ecosystems and value networks, this would be a useful extension to build a more comprehensive model of an increasingly important area of innovation.

The reliance on a small number of cases and close engagement with its idiosyncrasies inevitably limit generalized induction. For example, the focus on early stages of developing a potentially disruptive technology for medical and health industry prevents investigating managerial actions and organizational capabilities that become relevant when this technology enters the market and start disrupting its members. It is possible that in the latter stages the internal opposition to the initiative may intensify. It is expected that an incumbent introducing convergent innovation in a highly regulated field of medicine will face similar challenges as those identified by Ansari et al., (2016) when studying the disruptor's dilemma, but the current stage of this venture does not permit investigation of this empirically.

In terms of organisational routines and capabilities, there are three implications for future research. First, would be to encourage a more thorough investigation of how incumbents engage with potentially disruptive convergent technology in early stages of development as this complements innovation research that mostly investigates ex-post successes or failures. Second, that investigating disruptive and discontinuous changes potentially sheds more light on reciprocal relationships between managerial agency and development of organizational capabilities in general or innovation capabilities. Third, consistent with Garud et al,'s (2013) perspective on innovators embracing the complexity, there is evidence from the cases of organisations using a range of approaches to *integrate* activities and embrace, rather than try to reduce, complexity. This is not reported here in the interests of brevity, but will be followed up in future research.

The governance and decision making approaches have been highlighted, but existing approaches in both closed and open innovation do not adequately address the challenges. Further research in this field, and particularly the role of interpretive approaches and the role of external experts warrants further attention.

This research has suggested several exploratory and evolutionary processes to support convergent innovation. It has been tentatively suggested that these processes, to develop knowledge, the innovation, and value network are non-deterministic and analogous to adaptive walks (Kauffman and Levin, 1987). Approaches such as genetic algorithms (Grupe and Jooste, 2004; Holland, 1992; Kauffman et al., 2000; Mitchell, 1996) may provide further insights to the underpinning process. Given the human interactions, approaches built upon *anticipatory genetic algorithms* (Kosorukoff, 2001; Mocanu and Kalisz, 2012) may provide a fruitful area for exploration and would align with thinking on anticipatory systems (Louie, 2010) and systemic approaches (Fuller et al., 2000; Midgley, 2006, 2000).

Finally, as part of this research, an approach to studying business and innovation ecosystems was developed (PBSRDC), addressing a known gap in the literature, but the approach has only been tested to a limited extent. Further testing of this methodology in a range of different ecosystems, at different points in their lifecycle would help validate the proposed approach and increase its generalisability.

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Appendices

Appendix A1 - Preliminary Interview Protocol

Emerging Health Care Industrial Ecosystem – Understanding the Emerging Landscape - Interview Protocol – Exploratory Phase

Purpose

To gain insights from a wide range of experts and interested parties (stakeholders) into defining the overall 'system' boundaries and to identify the key challenges and potential opportunities for the development of Emerging Health Care systems (and specifically Convergent Medical Technologies (CMT)). To be used as part of a PhD Research Project.

These insights will be shared with interviewees in a follow up (probably via email) to further validate the key or summary findings.

Participants

- A diverse cross-section of Stakeholders in the Heath Care Industrial system (see page 2)

Approach

Following an initial focus group meeting, identify likely interviewees / stakeholders. During interviews review their view of stakeholders and key issues and opportunities. Use 'snowballing' to identify additional potential interviewees.

Early Research Hypotheses (related to the industrial ecosystem)

The initial research focuses on two distinct stakeholder groups – customers (ie NHS Trusts, CCGs, service providers) and Industrial System stakeholders (ie pharma, med tech, ICT, funders, academia)
From a customer or patient perspective:

- *Hypothesis H1 – There is a increased focus on patient centric approaches, from R&D, through to service delivery and commissioning, but the practical implications are not always clear*
- *Hypothesis H2 – current suppliers do not engage with customers well (or tend to engage late) and have limited understanding of customers needs*
- *Hypothesis H3 – suppliers do not have appropriate business models to meet customers needs*

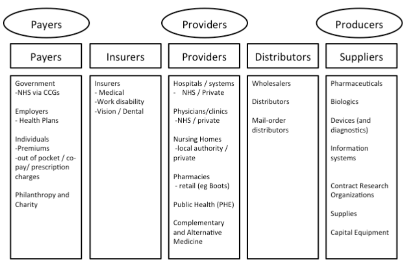
From perspective of Emerging Health Care Industrial System 'landscape", the key hypotheses are:

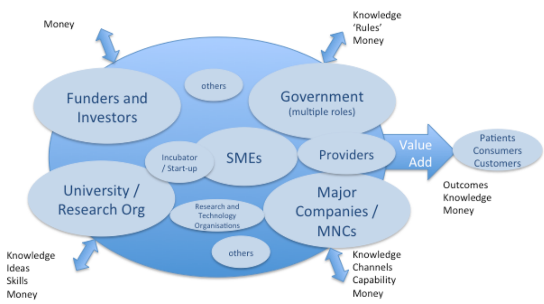
- *Hypothesis H4 – There is not a clear understanding of CMT, and there are divergent views across actors/stakeholders*
- *Hypothesis H5 –CMT challenges are diverse and underestimated*
- *Hypothesis H6 – The potential CMT customers are not clearly defined or understood*
- *Hypothesis H7 – There is limited and unfocussed support for CMT activities in UK*

Interviews will be conducted in March through July 1014 to establish the system boundaries and key issues to help shape subsequent research.

Interviewees – customers and stakeholders

From Burns (Burns, 2002, 2012) the immediate Value Chain consists of:



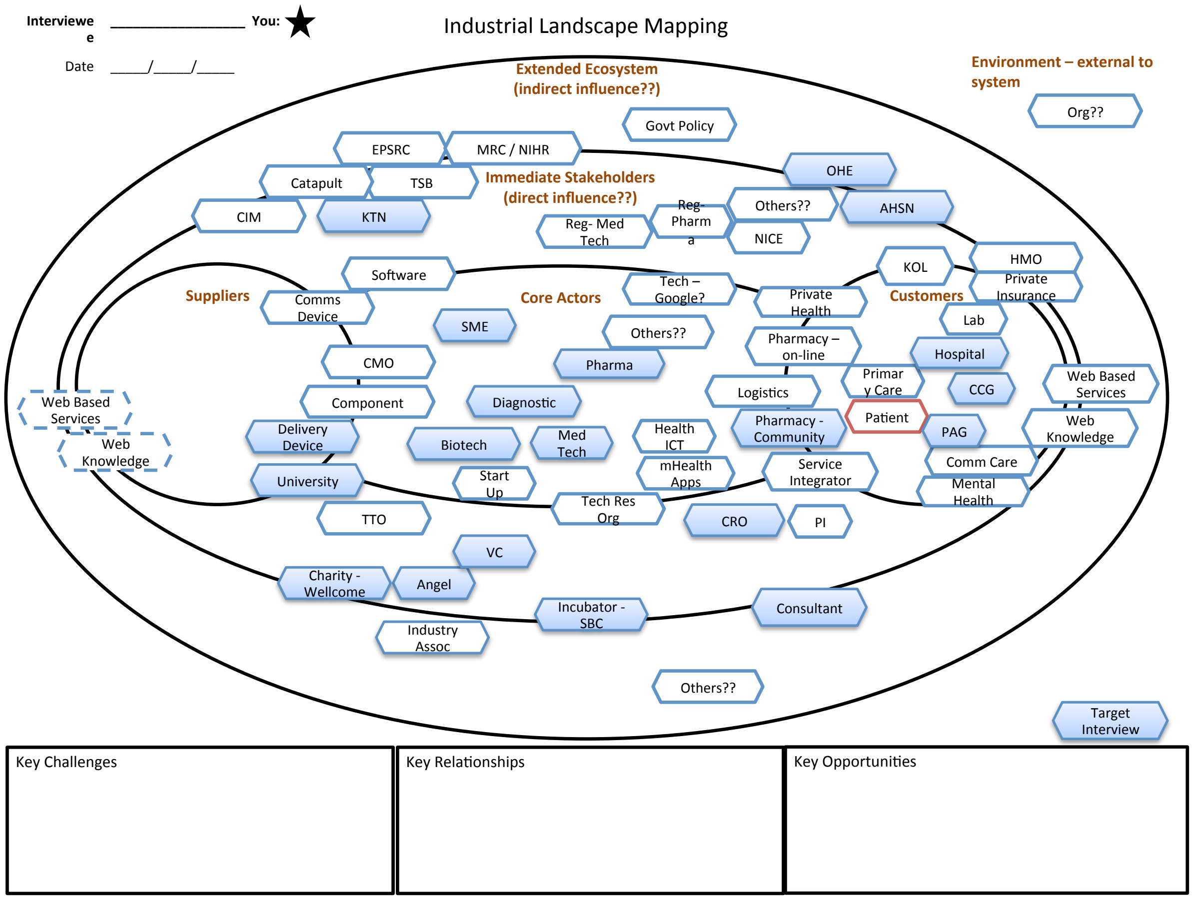


Mark A Phillips
Rev 4 July 2014

	Stakeholder	Role	Organisation Examples	Rationale for inclusion or exclusion in interviews	Comments – potential interviewees
1	Patient	Customer, consumer, payer	n/a	Exclude - Too diffuse, diverse and dependent on subject knowledge.	(Ethics issues)
2	Patient Group	**Collective of patient interests**	SPRING (Parkinsons)	Consider inclusion of 1-2 groups in next phase	Shift MS
3	Provider	Primary Care	• GP Practices	Consider for follow up (part represented by CCGs)	(Access issues)
4	Provider	**Secondary Care**	• Hospital Trust • Community Care Trust • Mental Health Trust	Include Hospital Trusts as major users Consider Community and MH in follow up Consider Mental Health as follow up, depending on CCG priorities.	Camden NHS Wittington NHS Kings College HNS Leeds & York NHS
5	Provider	**Pharmacy**	• Boots Alliance • Lloyds	Key community providers for products and services	Boots Alliance
6	Provider	New Integrator	• ??	Entrepreneur / innovator looking to offer provider services?	Scan for potential integrator
7	Payer	**Care Funding**	• CCG	Include as major funders and commissioning agents.	Enfield, Camden CCGs
8	Payer	Insurance	• Axa, BUPA	Consider for next round	(Access)
9	Payer	**Medical R&D Funding**	• AHSN	Include as major focus in NHS Innovation	Eastern AHSN
10	Producers	Distributors	NHS SC	Consider in later phase	Run by DHL
11	Producers	**Pharma R&D, and supply**	GSK, AZ, generics	Major therapy suppliers and R&D. include one MNC	GSK / J&J
12	Producers	**Med Tech R&D and supply**	GE, Siemens	Major Med Tech. include one from med tech or diagnostics MNC	GE, Roche Diagnostics
13	Producers	**Diagnostics R&D and supply**	GE, Alere, Roche, Biomerieux	Major diagnostic. include one from med tech or diagnostics MNC	Alere / Mologic Imanova
14	Producers	**eHealth**	TPP / DH	Include 2-3 from list	Tbc
15	Producers	**mHealth**	App developer	Include 2-3 from list	Via NHS Trust
16	Producers	**Services**	Accenture, TPP	Include 2-3 from list	Accenture
17	Producers	**Biotech – therapy**	Phagenysis	Include 2-3 from list – SME / SU	Phagenysis
18	Producers	**Med tech / device dev**		Include 2-3 from list – SME / SU	J&J
19	Producers	Suppliers to above	Chemical, electronics,	Consider in future phase, as suppliers to 'producers'	
20	Producer	RTO / CRO	PA Consulting Covance	Consider in future phase, as suppliers to producers	
21	Regulators	**Regulator**	MHRA FDA EMA	Include MHRA, if they will participate	MHRA Innovation?
22	Funder	**Angel / cVC/ VC / PE**	SVLS, SROne Imperial Innov Entrepreneurs Fund	Include - 2-3 to get views from different funders	Imp Innovation, SR One
23	Funder	Crowd source		Lack of content knowledge, maybe later depending on other funder input.	
24	Funder	**Charity / Trust**	Wellcome Trust	Include, as major funders	Cancer Research UK

Appendix A1

Proposed Landscape map for interview (example -part populated based on initial ‘focus group’ meeting). Will use a blank map as part of research process.



‘Customer’ stakeholders

Semi-structured Interview questions

Hypothesis 1 – There is a increased focus on patient centric approaches, from R&D, through to service delivery and commissioning, but the practical implications are not always clear

1.1 - What are current priorities for service delivery?

1.2 – To what extent is ‘patient centric’ embedded into commissioning, R&D, care etc?

1.3 – To what extent do you see an increased in convergent technologies being able to support these needs? What challenges do you foresee?

Hypothesis 2 – current suppliers do not engage with customers well (or tend to engage late) and have limited understanding of customers needs

2.1 – Have you come across recent R&D, new products or services? Did they meet your requirements? If not, why? What would you have liked to have seen differently?

2.2 – To what extent and how do they engage with you? Is the timing right? Would you like more, less, about the same engagement?

Hypothesis 3 – suppliers do not have appropriate business models to meet customers needs

Industrial Ecosystem / Value Network Stakeholders
Semi-structured Interview questions

Hypothesis 4 – There is not a clear understanding of CMT, and there are divergent views across actors/stakeholders

4.1 - What is your understanding of convergent medical technologies (CMT)? (Prompt with our CMT model, if necessary, and ask for feedback).   What is you view of this model?

4.2 - What was/is your 'role'?

- Innovator – entrepreneur, CMT 'company' (pharma, biotech, med tech, diagnostic, eHealth, mHealth, other), Supplier (to above)
- Care Delivery (prescriber, user), Customer / Buyer (patient, HCP, payer)
- Funder (VC, PE, other)
- Regulatory
- Academic, Industry Expert or consultant

4.3 - Have you seen any good examples of CMT activity? Summarise (concept, product, development phase).

Hypothesis 5 –CMT challenges are diverse and underestimated

5.1 - What are the biggest challenges in developing convergent medical technologies?

5.2 - What do you see are the key challenges for (your domain):

Hypothesis 6 – The customers are not clearly defined or understood?

6.1– For your own (or an example CMT product) are the customers and value clear?

- How is value defined (by whom) and how do you see it being captured?
- Who are the end users?   Who pays? How? On what basis?
- What is the proposed business model? What else is needed for it to be successful?

Hypothesis 7 – There is limited and unfocussed support for CMT activities in UK?

7.1 – What support exists to help deliver CMT technologies?

7.2 - What would be the most useful activities or capabilities to help support delivery of CMT?

7.3 - What role could (or would you like to see) SBC play in helping facilitate CMT, and increasing potential value?

Appendix A2 – Case Study Protocol (extract)

Case Study Data Collection Instruments (extracted from protocol)

Overview of the Case Study

Background

Globally, health care systems face major challenges to meet the ever-increasing societal demands and to control costs. Convergent technologies (those from other industries) have the potential to address some of these challenges, but they bring new complexities to innovators and the wider innovation ecosystem. This research focuses on innovators developing products and services using convergent technologies for health care.

This research, using an exploratory framework, interviews and a range of case studies, examines the challenges when developing convergent products and services for health care.

Aims

To understand how organisations (or alliances of organisations) undertake product development of convergent medical technologies in the emerging health care industrial system:

How do organizations develop convergent technology products for the emerging health care industrial ecosystem?

In addressing this question, the other aim is to develop and refine a Framework for Convergent New Product Development and a model that explicitly links value attributes to capabilities required.

Appendix A2

Table 1 – Systems Methodology (PBSRDC)

Aspect	Methodology	Activities
Boundary / Structural	Define the system, system boundaries, identify and map different system levels, hierarchies and sub-systems (modules) of relevance and key agents at the micro-, meso- and macro-levels	• Identify 'Stakeholder 'system' and boundaries • Identify Key Actors. • Map system and key sub-systems
Relationships	Understand the key interdependencies and relationships (e.g. contractual and governance) between agents, subsystems and between different system levels, with an emphasis on differing agent perceptions, local causality, non-linearities and dimensions (e.g. scale and power)	• Develop 'systems' map (using SSM) showing key relationships between key actors (stakeholders) and projects in this domain. • Identify influence-impact relationships between key stakeholders • Identify different perceptions of agents about key issues
Dynamics and co-evolution	Understand the system history. Identify major inputs and outputs, key processes, patterns and trends, with particular attention on the unexpected or 'new'	• Describe or map system/sub-system background (i.e. historical perspective of stakeholders) • Map Trends e.g. – social, economic, technological, legal, political and environmental • Map recent phenomena, issues and opportunities
Perspectives	Use different views and perspectives (both spatial and temporal) to broaden understanding, identify system changes and provide an opportunity for 'triangulation'.	• Use combination different interviewees and investigation approaches to provide different perspectives, including: ○ Infrastructure/ Incubator perspective ○ Focal firm versus alliance partner perspectives ○ MNC perspective and SU/SME perspective ○ Documents, observation versus interviews ○ Snapshot and longitudinal data

Table 2 – Stakeholder Analysis

Aspect	Consideration
Interest	The extent to which the issue is of interest or value to a stakeholder
Influence (power)	The relationship between the stakeholder and organisation (or alliance) and where the balance of power lies
Network Centrality and Density	The position of the organisation and stakeholder in relation to the network and the interconnectedness of that network
Relationships and continuity	The '*jointness*' of interests, interactions and their evolution over time.

Data Collection Questions

Table Q1 - Collection Instruments – General (Project Based Case Studies)

Organization	
Project / Product	
Key Alliance Partners (Develop 'ecosystem map')	
Interviewee(s)	
Date(s)	
Background Information on Organisation, New Products and 'convergence' • What is the project? Or innovation? • What commitment is the organisation making? • Is it 'strategic' and reflected as such? Or tactical or experimental?	

Table Q2 – Factors in Convergent New Product Development (for key organisations in convergent project)

	Factor	Example	Questions	Responses
F1	**Ecosystem and Market understanding**	Organisation undertakes activities to map and understand the ecosystem to keep pace with its evolution, and seeks to shape or reconfigure it to realise value.	How does organisation understand ecosystem? What routines are in place? Do these assess trends, technologies from other industries? How often are these updated?	
F2	**Stakeholder Management**	Map and engage stakeholders through the life-cycle of the development process to facilitate progress, and evolve relationships over time.	How does organisation identify and engage key stakeholders? What assessment of key stakeholders is undertaken during development?	
F3	**Customer Engagement**	Routines and capabilities to engage early in the development process with customers to inform product/service design and the potential business model options	How does organisation identify and engage key customers? Is there evidence of 'co-development'? How does this inform product development, the development process or the business model?	
F4	**Business Model development**	Map and understand the links between the business model and the required activities and capabilities.	How does the organisation define the business model? Is the link to the required capabilities clear?	
F5	**Value Attributes**	Map and understand the key components in value creation and value capture	Can value creation and capture be described? How is it assessed or validated?	
F6	**Governance**	Active senior management support and engagement in investment decisions. Adequate knowledge for project selection and progression through objective decision gates.	Are senior management active sponsors, supporters of convergence? What activities do they undertake to support this? Are they engaged in governance? What steps are taken to ensure adequate knowledge (incl trends) to assess projects (from both internal and external perspective, including Alliance Partners)	
F7	**Gate Criteria**	Objective Go / no go decision criteria to determine progressing to next phase, that consider external capabilities and paths.	Are there criteria for project progression? Are these clear and objective? Do they assess both internal and external factors?	
F8	**Process**	A process or methodology exists to guide process development and quality management	Does the organisation have a process for NPD? How does it compare to the 'typical' NPD process (see next questionnaire)?	

			How does it address Alliance partners?	
F9	**Risk Management**	Risk management processes are in place to address patient and user safety risks, and the combination of technological (execution) risks, product integration (co-innovation) risks and the business and commercial (adoption chain) risks	How does the organisation assess project and business model risk? Are there reviews that cover technological, integration (co-ordination) and business model risks? How are these integrated and reviewed? Is it explicitly tied to the governance process?	
F10	**Alliance Partners**	Inter-organizational co-operation via clarity in objectives and scope. Accessing capabilities through alliance partners, adopting different alliance management approaches to different partners. Addressing issues across co-innovation ecosystem.	How are alliance partners managed? What is the nature of the alliance (contractual, wider partnership, joint venture?) Is the same approach used to manage all partners? If not, how is it done? What is relationship to 'lead organisation'	
F11	**Project Team**	The core team has leadership, expertise and experience, and balances autonomy, accountability and empowerment within the governance framework	How are team leaders and key members selected? How accountable (and autonomous) is the team? To whom do they report? Does team include Alliance Partners? How?	
F12	**Support infrastructure**	Organisation builds and makes use of ecosystem and infrastructure to complement capabilities and support development	What support network or infrastructure has the organisation put in place? What activities are undertaken to join, create or build ecosystem?	

Table Q3 – NPD Process Observations (typical process for comparison)

Typical Stage Gate	Pharmaceutical Therapeutic	Medical Device or Diagnostic	Health ICT / App	Observations *Key activities, gate progression/criteria, management*
	Basic Science Research, Disease mechanism	Basic Science Research, Biological, opto electro mechanical basis		
Ideation and Screening	Product Discovery, Target Identification and Risk Analysis	Product Concept and Risk Analysis	Product Concept and Risk Analysis	
Scoping - Technical and Market Assessment	Target Product Profile	Design User Needs	User Needs	
	Candidate Selection	Design Input	Software Development Planning	
	Early Development		Software Requirements Analysis	
	Pre-clinical Testing (safety, DMPK)	Proof of Concept	Software Architectural Design	
Build Business Case	Commit to FTIH	Commit to Design Control		
	Phase I - Safety	Design Requirements, Detailed Design, Design Review	Software Detailed Design	
Development	Phase Iia - clinical efficacy	Functional Testing, Design Review	Software Unit Implementation and Testing, Review	
	Commit to Full Product Development			

Typical Stage Gate	**Pharmaceutical Therapeutic**	**Medical Device or Diagnostic**	**Health ICT / App**	**Observations** *Key activities, gate progression/criteria, management*
	Phase IIb trials - dose ranging studies, Phase !! Review. Finalise formulation, process development	Functional Integration, Detailed Engineering, Manufacturing verification and stability	Software Integration and Integration Testing, Review	
Testing and Validation	Phase III Clinical Trials, Market Access Studies, Verify manufacturing processes and stability	Clinical or Laboratory Outcome Assessment, Verification and Validation of Performance and Safety	Software System Testing and Verification, Review	
Launch	Regulatory Approval and Launch, Validate manufacturing processes	Regulatory Approval and Launch	(Regulatory Approval and) Launch	
Follow-up	Commercial Supply and Pharmacovigilance	Commercial Supply and Post-market Surveillance	Software Release, Commercial Supply and Post-market Surveillance	

Appendix A3 – Ecosystem Trend sources

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Appendix A3

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Appendix A4 – Ecosystem and case interview sources

Table A4-0-1 Further ecosystem interview sources

ID #	Interviewee Role	Organisation Type	Date	Approx. Interview Duration (mins)
ECO28	Senior Manager	NICE	26/02/2015	60
ECO29	Senior Manager	NIHR	03/03/2015	45
ECO30	Director	CEO Innovator	04/03/2015	45
ECO31	Professor (biosciences)	University Research	19/03/2015	60
ECO32	Professor (additive manufacture)	University Research	08/04/2015	60
ECO33	Director	Innovate UK	04/06/2015	60
ECO34	Senior Manager	MedCity	11/06/2015	60
ECO35	Senior Manager	Office Life Sciences	18/08/2015	60
ECO36	Senior Manager	PM Catapult	01/09/2015	60
ECO37	Director	ITHealth and SBRI	20/10/2015	90
ECO38	Director	SBRI, Health Trust	06/11/2015	60
EC039	Non-Exec Director	Health Enterprise	21/04/2016	60

Table A4-0-2 Case CMTI interview sources

Informant Code	Informant title	Number of Years at current company (or in industry)	Number of interviews	Hours interviewed
CMTI1	CEO	3 (20 in industry)	2	3.5
CMTI2	Business Development	3 (10 in industry)	1	1
CMTI3	Board Member, and Entrepreneur	2 (25 in industry)	2	2.5
CMTI4	Convergent Team Member	20 in industry	1	1
CMTI5	Board Member, Entrepreneur	2 (26 in industry)	1	1.5
CMTI6	Chairman	3 (30 in industry)	1	0.5
CMTI7	CEO of convergent Innovator	2 (14 in industry)	1	0.5
CMTI8	Convergence Team Member, external consultant	1 (17 in industry)	1	1

Table A4-0-3 Case NMD interview sources

Informant Code	Informant title	Number of Years at current company (or in industry)	Number of interviews	Hours interviewed
NMD1	Vice President and Head	10 (15 in industry)	4	4
NMD2	Business Development Director	10	3	3.5
NMD3	Head of Venture Funding	3 (11 in industry)	2	2.5
NMD4	Director and Head of Research group	18	2	2.5
NMD5	Director and Head of Technology	1 (6 in academia)	1	1
NMD6	Academic Partner (Professor)	26 (academia)	1	1.5
NMD7	Incubator Partner	4 (25 in industry)	2	2
NMD8	Incubator Entrepreneur	3 (20 in industry)	1	1

Table A4-0-4 Case DH1 interview sources

Informant Code	Informant title	Number of Years at current company (or in industry)	Number of interviews	Hours interviewed
DH1-1	Founder and CEO	3 (20 in industry)	8	10
DH1-2	Senior Project Manager	2 (10 in industry)	2	2
DH1-3	Board Member, and NHS Trust Director	2 (22 in industry)	1	1.5
DH1-4	Board Member, and Senior Manager in Provider	24 in industry	1	0.5
DH1-5	CEO of Technology group (developer)	7 (26 in industry)	2	1
DH1-6	NHS Trust Finance Director (governance)	21 in industry	1	0.5

Table A4-0-5 Case MLD interview sources

Informant Code	Informant title	Number of Years at current company (or in industry)	Number of interviews	Hours interviewed
CMTI1	CEO	1 (3 in industry)	12	12.5
CMTI2	CSO	1 (3 in industry)	1	1.5
CMTI3	Chairman	<1(25 in industry)	1	1
CMTI4	Potential Investor / VC Fund	5 (20 in industry)	1	1

Table A4-0-6 Case DH2 interview sources

Informant Code	Informant title	Number of Years at current company (or in industry)	Number of interviews	Hours interviewed
DH2-1	Founder and CEO of venture	1 (15 in industry)	3 (1 joint)	3
DH2-2	Chairman	1 (30 in industry)	3 (1 joint)	3.25
DH2-3	Med Tech Consultant (potential future Board member)	24 in industry	1	0.5

Appendix A5 – Case ECPO analyses

This appendix contains the causal analysis, using the ECPO method for each case.

A5.1 Case CMTI ECPO analysis

See Table 6-5 in main text.

A5.2 Case NMD ECPO analysis

ECPO Analysis
Case: NMD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries (F1-F12)	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
e1	Meetings with researchers and other stakeholders (F1)	c1	Nascent ecosystem, key actors not established, knowledge gaps in ecosystem	p1	Need to identify potential partners, collaborators, sources of knowledge or experimental work needed to d**evelop overall strategy and reduce risk**	x1,1	Systematic searching (literature)	Garud, Pandza - strategic search. Ferreras-Mendez et al. Salter.	Yes - there is a need to identify where knowledge resides, it is new to the organization	o1	Strategic Search (both local and distant - using structured and snowball approaches)	02/10/15 NMD3 - "[xx] is wide space and most of the work is in specific diseases, so that was our focus …. searching this way, the approach works well in molecular drug discovery, but for [xx] it is a little different. We start by looking at the basics [DISTANT/BROAD] in physiology, what are the target functions, is there a neural complement, then we look to build evidence of innovative studies in the literature or other supporting things [LOCAL/DEEP} "
		c2	Limited funding of academic researchers			x1.2	Use range of approaches to increasingly engage a wider audience. Use network to extend search (snowball)	Goodman - snowball	Yes - it is a novel area, so need to scan 'distant' knowledge and sources	o1	Strategic Search (both local and distant - using structured and snowball approaches)	02/10/15 NMD3: "So, … it was structured to an extent. A bit like a structured fishing expedition. We tried many different ways"
										o1	Strategic Search (both local and distant - using structured and snowball approaches)	02/10/15 NMD3: "...it's like a bit like a deep dive in…and reflecting and then looking in another area…an iterative process…and trying to make sense of it, so do I have enough information, is it meaningful?"
		c1	Key ecosystem players not identified.			x1.2	Use range of approaches to increasingly engage a wider audience	Goodman - snowball	Yes - as knowledge is new, there is a need to exchange and challenge to build understanding	o1	Strategic Search (both local and distant - using structured and snowball approaches)	22/10/16 NMD1: "We decided to hold a conference and persuaded the NIH (amongst others) to be involved, that encouraged attendance (from academics looking for funding) at the conference, and from that we found our next wave of collaborators. So of the original three, we are not actually working with them now. But their interaction was important. Following the conference we identified and engaged 10 others where there was a sweet spot, common interests and they formed the basis of the next wave of the network. They helped us get to a proof of principle for the venture. We've now expanded that to over 30 collaborators and we also have 15 other collaborators working on technology challenges (Innovation Challenge). We also have our Scientific Advisory Board for therapies and engineering, which opens up a wider and different network."

ECPO Analysis
Case: NMD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries (F1-F12)	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
		c3	Knowledge and technology gaps in ecosystem			x1.3	Interchange of idea and challenges - sense-making	Gioia, Weick, Daft and Lengel - sense-making	Yes - as knowledge is new, there is a need to exchange and challenge to build understanding	o2	Sense-making via diverse stakeholder interactions and an integrating role	12/03/15 NMD4" ".. we engaged our external community, the institutions, academics and conference attendees and from their output we created a second white paper"
						x1.4	Acquisition of knowledge for NMD - direct purchase of IP	Rong - nurture	No - acquiring knowledge now offers some control, but risks undermining ecosystem (Rong)			
						x1.5	Internet searches (systematic?)	n/a	No, Only partial solution, lacks ability to address equivocality (Daft)			
						x1.6	Attend Conferences to meet, connect and share information	Daft - diversify search	Only partial, very limited network, attended but did not expand network - close network			
e2	Creation of White Paper and other journal papers (F1)	c2	Field not established or widely recognised. NMDs role in it not established.	p2	Establish field and **need for funds for basic research**	x2.1	Interchange of ideas and challenges - to create known/unknown knowledge domains	Gioia, Weick, Daft and Lengel	Yes - need to identify where knowledge resides	o2	Sense-making via diverse stakeholder interactions	12/03/15 NMD4" ".. we engaged our external community, the institutions, academics and conference attendees and from their output we created a second white paper"
		c3	Limited sources of funding			x2.2	Raise awareness and understanding with funders	Boundary object - educating potential collaborators - Carlile	Yes, reduces perceived risk	o2, o5	Sustaining - investing in known gaps to address ecosystem 'holes'	22/01/16 NMD1: "So it went something like this. We started with a systematic search, but I'd downplay that, we aspired to it, but that's not how it worked out over time. That initial search led to us accessing three key individuals who we collaborated with to write the Jump Start (Nature) paper. That provided a key to access more people. It was not so much that
		c4	Knowledge and technology gaps in ecosystem									

Appendix A5

ECPO Analysis
Case: NMD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries (F1-F12)	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
												they opened up their Rollerdex, as by working with them we had more credibility from those interactions and the paper in Nature, so we were perceived as serious and credible. That was key."
		c6	Researchers moving away from field due to lack of funding	p3	Establishment of **viable R&D community**	x2.3	Selection of areas requiring focused investment	Daft	Yes - sustaining action to ensure key academics remain	o2, o3, o5	Selection to ensure. Key researchers remain in the ecosystem (e.g. sustain)	16/11/15 NMD4: "We know from discussions that researchers who were in this space moved away because of lack of funding."
e3	Using media to put out firms interest and information about the field (F1)	c2	Field not established or widely recognised. NMDs role in it not established.	p4	Need Increased awareness & visibility. Need to b**uild NMD presence**	x3.1	Broadening the audience. Getting some of the ideas in to more mainstream media to help influence.	Boundary Object - educating potential collaborators - Carlile	Yes - need to increase awareness to attract interest and partners	o2, o6	Sense-making via diverse stakeholder interactions - create visibility	Various articles in Nature Medicine, New Scientist, Nature Biotech, Reuters, Financial Times in Q2/Q3 2013 and Q2 2014
e4	Organise collective meetings of researchers and other interested groups (F1, F2)	c1	Nascent ecosystem, key actors not established, knowledge gaps in ecosystem	p5	Need to develop wider and stronger ecosystem links	x4.1	Interchange of ideas and challenges - to create known/unknown knowledge domains	Gioia, Weick, Daft and Lengel	Yes - need to identify where knowledge resides, but equally encourage more collective engagement to create viable ecosystem	o2, o4, o5	Shaping and Sustaining - investing in known gaps to address ecosystem 'holes'	MS 09/01/14: [NMD] is taking a low-key stance as a facilitator of ideas rather than trying to dictate the terms of engagement. "Our objective is to add value, and we do that in two ways: by encouraging more scientific diversity in the field, and helping prioritize a few practical outcomes thorough funding and partnerships that animate a spirit of co-ownership."
e5	Award of R&D projects to external partners (F10)	c2	Lack of funds for researchers. Need to de-risk early on.	p4	Need to build 'presence' in field	x5.1	A combination of risk reduction and early projects to demonstrate potential and capability. Plus engagement of external community	Schreiner; Kale & Corsten; Duane Ireland, Hitt	Yes - Shape using Alliances via setting research agendas and providing funding. Also increases 'presence' in field	o3, o4, o5	Shaping (and sustaining)	12/09/12 Internal Launch Paper: "In the first half of 2013 we will activate the global research community by awarding up to 10 exploratory grants to research groups for proof-of-principle testing of attractive disease intervention hypotheses."
												26/01/16 NMD6: "They are like a catalyst and have open up new possibilities, provided a new purpose. I was almost ready to retire....but this research provides a new perspective."

ECPO Analysis
Case: NMD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries (F1-F12)	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
e6	Used ecosystem to map out and identify knowledge gaps	c1	Nascent ecosystem, key actors not established, knowledge gaps in ecosystem	p5	Need common understanding and areas to focus for investments	x6.1	Sense-making (Wieck) - recognising need to plug the gap and engaging ecosystem to define it.	Wieck - sense making	Yes, reduces overall risk. Also significantly enhances NMDs position in the ecosystem.	o2, o5	Sense-making and Sustaining	16/11/15 NMD4 Interview: "We mapped out the challenges and opportunities. The consensus was that the community needed a device, a chronic implant that could be used to help in certain disease models and in normal physiological conditions"
						x6.2	Seeking to exploit gaps	Doz	No, not evidence of moving to exploitative action			
e7	Open Innovation Challenge to address ecosystem technology gaps (F1, F2)	c5	Need technology solutions to fundamental measure, monitor, neural connections	p1	Need to find potential solutions in ecosystem and beyond	x7.1	Searching and engaging others to identify issues	Wieck - sense making	Yes - actively engaged other to help make sense of gap, solution and approach	o2, o5, o6	Sense-making and Sustaining, and raising visibility	16/11/15 NMD4: "We also consulted with a lot of academics and about it would need for them to participate (so we could be sure we'd have people competing for the prize). We had originally considered a $1M prize, but it became clear it would need to be higher, so we set the prize pool at $5M, $2M for phase 1 (10 teams) and $3M for phase 2 (3 teams)."
						x7.2	Identified need to modify approach as they developed it.	Teece et al - dynamic capabilities - experiential learning	Yes, partial, Incremental changes to process	o5, o9	Sustaining, but **evolving process**	16/11/15 NMD4: "So in summary, after the community identified the 'problem' we went out and consulted to confirm we had identified the right problem and decision criteria, we also got the funders to endorse and confirm this was critical and finally we checked that the community would be prepared to participate. So it was methodical, but it evolved. "

ECPO Analysis
Case: NMD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries (F1-F12)	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
e8	Meeting to review OIC progress and share knowledge (F2)	c6	Identified gap in technology. Impacts NIH funded projects, and NMD development plans.	p6	Need Technology in place to enable innovation and NMD venture to develop.	x8.1	Sharing knowledge across projects and then looking for best forward approach	Wieck - sensemaking. Garud - creating events	Yes - Sense-making via diea and knowledge sharing plus Shaping via setting research agendas and providing funding.	o4, o7	Shaping - balancing in near and long term aspirations	03/12/15: NMD4 interview: "In May we are getting the 10 teams together in LA to present their work so far and share ideas and learning. We have also invited some major tech players (consumer electronics) who may be able to help or work across teams to provide solutions. We are hoping that from this we will have stronger proposals going into Phase 2."
e9	Investing in ecosystem and shared IP (F9)	c4	Ecosystem knowledge and capability gaps will inhibit innovation	p7	Need to balance addressing ecosystem gaps and creating an increased credibility for NMD	x9.1	Sense-making (Wieck) - recognising need to plug the gap. Sustaining - intent to address gap.	Wieck - sensemaking	Yes, reduces operall risk. Also signficantly enhances NMDs position in the ecosystem.	o5, o8	Sustaining (and credibility-seeking)	16/11/15 NMD4 Interview: "So we want to work in a truly open innovation way, to create opportunities but we recognize potential skepticism, our integrating role might be seen as undue influence. But its actually more about stimulating the ecosystem, in practice we cannot access that funding, only academics can. It might seem a little altruistic but its really about helping to catalyse the field. We know from discussions that researchers who were in this space moved away because of lack of funding. "
		c7	Researchers sceptical of intent? And would 'take the IP' from researchers	p8	Deliberate and open approach to open innovation and IP sharing	x9.2	Sustaining - intent to address gap, but also provide support to ecosystem (by IP sharing)	Wieck - sensemaking	Yes, Signficantly enhances NMDs position in the ecosystem.	o5, o8	Sustaining (and credibility-seeking)	15/08/16 NMD4: "And if you look at P&G, when they do OI, they put it out, but then they take all the IP and they exploit it for own commercial reasons. But this was different. But when we put it out, everyone viewed it as like P&G. But actually it was very different."
e10	Meetings with Government funding agencies (F1, F9)	c9	Limited funding for field by US , EU and Asian agencies	p2	Need to persuade funders to address funding gaps	x10.1	Sense-making (Wieck)	Wieck - sensemaking	Yes, highlighting the potential and the lack of academic funding, can help influence policy.	o5, o6	Sustaining - providing opportunities for others to support the ecosystem	15/08/16 NMD4: "So we have been very careful that we are advocating for the future field, as opposed to trying to influence a particular pathway, that may be beneficial to [NMD]"

ECPO Analysis
Case: NMD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries (F1-F12)	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
				p9	Avoid being seen to unduly influence government spending	x10.2	Sense-making (Wieck)	Wieck - sensemaking	Yes, NMD is UK based and main funding is US. Important to be seen to be 'neutral' and not unduly influencing.	o4, o5, o6	Shaping and Sustaining, increasing visibility and legitimacy	15/08/15 NMD4: "...our engagements with NIH and DARPA have been constructive. That is not what has been difficult. What has been difficult is managing the external perception amongst the US community and established medical device companies that are predominantly US based. We are this 'new kid on the block', with no historical medical device 'nouse', who are now suddenly shaping this huge field. "
e11	Meetings with Charities (F1, F9)	c8	Limited funding for field research based Charities	p2	Need to raise awareness of potential and address funding gaps	x11.1	Meetings to advocate field and funding needs	Wieck - sense making	Yes, Important to be seen to be 'neutral' and not unduly influencing.	o4, o5, o6	Shaping and Sustaining	*See Above*
e12	Flexible approach to alliance and partner management (F10)	c9	Different needs and capabilities of partners	p10	Need differing approaches to reflect differing capabilities and risks	x12.1	Partner Selection	Schreiner; Kale & Corsten; Duane Ireland, Hitt	Yes, Alliance management and relationship building is critical	o9	Flexible management of alliances	03/12/15 NMD4 Interview: "We have learned, that when investing in a company like [P1], with other investors, with a seasoned management, that we only need a low level of involvement. Compared to [P2] where we have daily interaction, helping guide their management."
						x12.2	Building partner relationships and trust					24/03/15 NMD5: "All the formal contracts are essentially the same but each is managed differently. And as contracts have matured we've moved from formal to more informal management. That interaction with the academics is really important."
						x12.3	Need to update and change processes	Ambidexterity - Birkinshaw	Partial - evidence of different capabilities across wider organisation, but no evidecne they are brought into play. Team is making small changes, by design and experiential feedback	o9	Appear to make quite small changes. Some are in response to previous experience (ie OIC), some are by design from the outset (ie VC fund)	Pattern of changes across multiple interviews and activities - see examples in other rows (o9)

Appendix A5

ECPO Analysis
Case: NMD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries (F1-F12)	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
								Dynamic capabilities - Teece et al	Partial - no evidence of systematic use of SST. More about small changes and management agency?			
e13	Meet academic alliance partners every 6 months (F10)	c10	Dispersed knowledge, academics do not know each other well.	p11	Share information, to broaden understanding, build alliances and affirm NMD position	x13.1	Regular meetings, curate and hosted by NMD.	Schriener; Kale; Duane Ireland, Hitt	Yes, Alliance management critical, regular meetings reinforce delivery of objectives, building relationships etc	o9, o5	Flexible management of alliances. Helps sustain and grow ecosystem connections	20/02/15 NMD3: "...bring researchers together every 6 months. (we have done it 3 times so far). Their are Funded PIs meetings, so they meet other PIs. Provides an opportunity to share results. Enables some networking. As a result some PIs now working together on other projects."
e14	Early project commitments in the field (F8, F9)	c11	Need to de-risk and show potential value	p6	Need to find potential solutions in ecosystem and beyond	x14.1	A combination of risk reduction and early projects to demonstrate potential and capability	Sarasvathy - effectuation?	Yes, looking to de-risk but also shape their offering and determine the field	o5,o6	Shaping	19/06/15: Strategic Plan: These front-runner projects will collectively provide the biggest de-risking for the [NMD] endeavour over the next three years, so choosing the right approach, doing the work right the first time and driving forward the right projects with urgency is key. We want to drive through enough projects to ensure we have a balanced portfolio of risk, taking into account possible attrition yet quality comes first.
e15	Creation of Internal Business Plan	c12	Need for internal governance and investment	p12	Use existing project approval and governance approach	x15.1	Selection, Investment and internal selling of proposal	Bettis & Prahalad, Tripsas & Gavetti, Danneels	Yes, existing Governance and Selection processes require business plan	o3	Selection	NMD Business Plan document

ECPO Analysis
Case: NMD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries (F1-F12)	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
e16	Team that formed strategy is also executing it (F11)	c13	Limited resources with skills internally	p13	Ongoing Interest and commitment	x16.1	Consistency and have Agency	Garud	Yes, have strategy and ongoing commitment	o8	Management Agency to incrementally change processes	16/08/16 NMD4: "Because you have the same people shaping the strategy and then executing, we have stayed true, by and large, to that original ethos and direction. Because what normally happens with strategy is people formulate it, they hand it over, and once you hand it over…the next person wants to shape it in their own way and the original ethos and direction is lost."
e17	Team built from diverse individuals with in-company knowledge, R&D expetise and external specialist technical expertise.	c13	Lack of internal capability	p14	Acquire adequate internal capability	x17.1	Investment in capabilities and skills	Teece, Winter et al	Yes, need to build new capabilities, but build them on existing (dynamics capability?)	o5, o8, o10	Sustaining, balancing need for external and internal capabilities	22/01/16 NMD1: "Towards the end of my time in the Strategy group, before I moved into a [...] role, I was asked to find a leader for BE. We spent months courting top academics in the field and eventually offered 3 candidates to [...]. He interviewed them, rejected all of them and over the summer, came back and said we wanted me to do it. So, I think he was trading off two things here. To make this venture a success we need to do two things – make the right scientific calls (and clearly the external candidates were better placed to do this), but we also needed to navigate the internal organisation. And the view was that they would not be able to do that as well. "
				p14	Acquire adequate internal capacity	x17.2	Investment in team, resources	Teece, Winter et al	Yes, need to build new capabilities	o6	Sustaining - creates capability internally	16/08/16 NMD4: "There are 30 of us now, managing over 50 academic collaborations. That's not including the funding agencies, OI challenge, Venture fund, plus philanthropic and management of upcoming JV."
e18	Presenting updates to other related science and technology events	c2	Increase awareness of field and NMD	p15	Increase awareness and NMD's 'innovator' role	x18.1	Using repeated, ongoing communications to increase 'voice'	Sense-making, Sense-giving (Wieck) and Shaping	Yes, sharing information with ecosystem actors and potential ecosystem actors fosters knowledge exchange and the firms position.	o2,o4, o6	Sense-making and Shaping innovation	"And we aren't slowing down. We continue to look at new ways to innovate in the healthcare space. In fact last year at SXSW 2015, we presented our work on biosensors in partnership with McLaren. And this year for SXSW 2016, we're presenting our work on bioelectronic medicine in a session called Inner Space: Bioelectronics and Medicine's Future."

ECPO Analysis
Case: NMD

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		c2	Need to increase presence and credibility in field	p16	Still not fully trusted in ecosystem, want to improve their position.	x18.2	Undertake activities to underpin and provide tangible evidence that they will do what they said	Shaping (Sitoh, Sarasvathy)	Yes, clear case evidence want to shape destiny and back up words with deeds. Creating path.	o2, o4, o7	Sense-making and Shaping innovation to improve legitimacy and position for advantage	15/08/16 NMD4 Interview: "So we were sticking to our whole OI ethos. We are not going to hide information. We want you to share your outputs, we will look for synergies. We will review your phase 2 presentations in the light of you all knowing where everyone else is. So that is embracing that spirit."
e19	Taking an increasing leasdership role in rhe field	c2	Nascent ecosystem, with no natural lead company	p17	Moved from a position to help create field to a leadership position.	x19.1		Sustaining and Shaping	Moved from Sustaining and credibility-seeking position to a Shaping and advantage-seeking position	o5, o7	Advantage-seeking behaviours, to move to exploitative position	15/08/16 NMD4: "I think our initial deliberate role was to integrate the community. To bring all those people in the community together. That then organically morphed into an expectation that [NMD] will evolve from playing an integrating role into a leadership position. So I wouldn't say, that from the outset we said 'we are going to be leaders', this is what's going to happen. We said, hey we are new to this field, let's bring all those people together let's work on what to do collectively to move this forward to bring treatments to patients. Along that journey we became the natural leader."
e20	Changes to Open Innovation Challenge (funding and process)	c1	Limited number of responses, lack of potential partners or knowledge of NMD	p18	Need to get adequate competitors into challenge to make it work	x20.1	Engaged ecosystem to better understand the challenge and what was needed.	Wieck - sense making	Yes, engaged and then refined OIC	o2, o5, o8	Sense-making and Sustaining by using small changes	16/11/15 NMD4: "We had originally considered a $1M prize, but it became clear it would need to be higher, so we set the prize pool at $5M, $2M for phase 1 (10 teams) and $3M for phase 2 (3 teams)."
e21	Using ecosystem to help define criteria	c13	Lack of internal knowledge and capability	p19	Desire to get criteria right and build partnerships	x21.1	Sense-making, Selecting	Selection and Sense-making	Yes- where defined criteria cannot be used, engaging others reduces risk of bias (Kahnemann Tversky)	o2, o3, o6, o10	Sense-making to re-risk decisions (selection)	15/08/16 NMD4: "So in summary, after the community identified the 'problem' we went out and consulted to confirm we had identified the right problem and decision criteria, we also got the funders to endorse and confirm this was critical and finally we checked that the community would be prepared to participate. So it was methodical, but it evolved."

ECPO Analysis
Case: NMD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries (F1-F12)	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
e22	Setting up internal governance	c14	Increasing R&D Investment	p20	Need to be seen as on 'similar' playing field to other R&D ventures	x22.1	Sense-making, avoiding internal cognitive inertia or rejection	Bettis & Prahalad, Tripsas & Gavetti, Danneels	Yes- reduces risk of internal rejection	o8	Internal acceptance, by creating sense of familiarity in how governed.	22/01/16 NMD1: "A lot of our work is based on external collaborations. So we modelled the R&D Unit on previous academic collaborations. ... So it made sense that the governance also followed."
												22/01/16 NMD1: "As our effort ramps up and our spend increases we inevitably end up in a trade off with other R&D areas. There is a fixed R&D pot and we are competing for some of it. So it is crtical you have good governance, especially as our efforts have effects in other areas of R&D). We need to have rigour in our capital allocation and ensure we have the right expert input. Hence the new Investment Board."
						x22.2	Ensuring new practices look similar or familiar to exsiting organisation	Lounsbury & Glynn	Yes, skilled cultural entrepreneurs	o8	Internal acceptance by making processes and structures look similar / familiar to others. Reducing perception of difference and 'risk'.	NMD1: 'I think there is also an element of familiarity. It's partly about giving Exec management comfort. ... It also helps across the rest of the organisation. We don't want to be 'seen' as too different. You should not underestimate the power of your peers. They can challenge, especially in R&D and we are all trying to access the same funding pot. So, there is a need for some familiarity, for people to be comfortable that the process, governance and arena is fair, it's different but seen to be fair. So, it isn't easier for us to get money that someone else.... The structures looked similar or familiar, like … an Investment Board. So, we looked like we were on the same playing field as other R&D groups ... although clearly we were making different decisions and we used different criteria'."
e23	Seeking a Joint Venture (F10)	c15	No major partnerships exist in ecosystem	p21	Need to have capability to move into development in near term	x23.1	Creating alliance with an organisation with complementary capabilities	Schreiner; Kale & Corsten; Duane Ireland, Hitt	Yes, Alliance management necessary to build capability quickly.	o4, o7, o9	Advantage-seeking behaviours, via alliance	02/08/16: [NMD] is far from being the only corporate player in bioelectronics — several other biotech, medical devices and computer companies are involved — but no one else has made such an ambitious long-term commitment. {Financial Times)

ECPO Analysis
Case: NMD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries (F1-F12)	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
e24	Change in JV negotiations	c16	IP negotiations protracted and difficult	p22	Need for controlling position as moved into development	x24.1	Creating alliance with sufficient control to exploit IP and create advantage	Schreiner; Kale & Corsten; Duane Ireland, Hitt	Yes, whilst an alliance was critical, the terms needed to enable advantage and value capture.	o9, o10	Advantage-seeking behaviours, to move to exploitative position	13/10/16 NMD1: A quite fundamental concern from [NMD] side was…we didn't want to invest together with a technology company to create a field and enable it and then that technology company has the right to form another partnership and build ... devices, because then we would not realize our investment. The benefit would flow elsewhere. We did not want an IP position where the other company would be able to take the IP and take all the value.
e25	Forming Joint Venture	c17	Revisited previous potential partner, they had progressed quickly and quickly found common ground	p21	Ability to create a viable JV quickly	x25.1	Creating alliance with an organisation with complementary capabilities	Schreiner; Kale & Corsten; Duane Ireland, Hitt	Yes, Alliance management necessary to build capability quickly.	o7, o9	Advantage-seeking behaviours, to move to exploitative position	13/10/16 NMD1: Now, the JV provides funding to do things differently. And, yes, we are moving out of […] a little but it is still 55% [NMD] and we have control. And the ability to capture value.

A5.3 Case DH1 ECPO analysis

ECPO Analysis
Case: DH1

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
e1	Use of "Hack Days", mobile tools, twitter etc to engage with users, patients etc	c1	Poor understanding of opportunity and that existing 'Apps' did not deliver user needs	p1	Ensure DH1 had access to patient / user needs	x1.1	Crowdsourcing for inputs and solutions	Chesbrough - open innovation	Yes - well established mechanism	o1	Strategic Search (crowdsourced)	*Multiple evidence on DH1 website, via Open Calls and on regular Twitter feed*
e2	Workshop Meetings and design sessions with patients, carers, practitioners (e.g. engagement days, discovery days)	c1	Poor understanding of opportunity and that existing 'Apps' did not deliver user needs	p2	Need to identify collaborators, sources of knowledge to ensure solutions were	x2.1	Systematic search	Garud, Pandza - strategic search	Yes - there is a need to identify where knowledge resides, it is new to the organization	o1, o2	Strategic Search (both local and distant - using structured and snowball approaches) and sense-making via engagement	*We are well connected locally and continue to spend a lot of time networking. We are always making new connections. We are reasonably well known locally, so people come looking for us too. More broadly we are connected to NIB and some of their work streams; so that gives us an opportunity to influence at national level, particularly on Open Source software strategy. DH1-1.*

ECPO Analysis
Case: DH1

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
		c2	Ecosystem of potential partners did not exist at the outset. Increase awareness across ecosystem		appropriate and acceptable.	x2.2	Use network to extend search (snowball)	Goodman - snowballing Rosenkopf / Nerkar- distant knowledge	Yes - it is a novel area, so need approach to scan 'distant' knowledge and sources	o1, o6	Strategic Search (both local and distant - using structured and snowball approaches)	*Involving people who have lived experiences can really help. There is real opportunity, provided its done in the right way (not patronizing). The benefits of peer support can be realised, so there is a less paternal model (which can damage people's self esteem, 'telling them how to live'). It might give people more power and help with their digital skills too, to make them more employable. So lots of benefits or opportunities. DH1-4*
		c3	Knowledge and technology gaps across ecosystem (especially in user groups)			x2.3	Interchange of idea and challenges - sense-making	Gioia, Weick, Daft and Lengel - sense-making	Yes - as knowledge is new, there is a need to exchange and challenge to build understanding	o2, o6	Sense-making via diverse stakeholder interactions and an integrating role	*What we did in December was an open call, we were looking to incentivize interest. So we got several teams and questions. Many of the solutions people were looking for are website based (quite common) or something to do with workflow (which is IT related) - DH1-1*
e3	Open calls and 'crowdsourcing' projects	c4	Care and pathways problems were not well identified within the ecosystem	p3	Need to engage users in identify (real) problems and potential solutions	x3.1	Interchange of ideas and challenges - to create known/unknown knowledge domains	Gioia, Weick, Daft and Lengel - sense-making	Yes - as knowledge is new, there is a need to exchange and challenge to build understanding	o2, o6	Sense-making via diverse stakeholder interactions and an integrating role	*see above*
		c1	Poor understanding of opportunity and that existing 'Apps' did not deliver user needs			x3.2	Everyone else is doing, so need to do, to 'play the game'	Need to follow	No, DH1-1 very principled, and DH1 has limited resources so only does what is essential.			*no evidence*
e4	Meetings with NHS Trusts, CCG and LCH	c5	Limited sources of funding	p4	Establish need for funds for venture development and technology platform creation	x4.4	Raise awareness and understanding with funders	Carlile, Leigh-Starr - boundary object - educating potential collaborators	Yes, reduces perceived risk	o2, o6	Sense-making via diverse stakeholder interactions, increases visibility.	*It' s about education, marketing awareness, that will create market pull and accelerate changes…so it's about PR, marketing. So, it will be about getting some examples of good practice out there…and not or limiting the number of counter examples… that create noise. DH1-5*
		c3	Knowledge and technology gaps across ecosystem (especially in user groups)									

ECPO Analysis
Case: DH1

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
		c5	Prior digital solutions not delivering promise	p5	Establishment of users' needs and expectations in terms of functions and features	x4.5	Simple response to bureaucratic governance, control of agency	governance / agency	Yes, partial	o2, o3	Selection - decision making criteria	
e5	Mapping stakeholders and ecosystem	c6	Nascent ecosystem, key actors not established, knowledge gaps in ecosystem	p6	Need to develop wider and stronger ecosystem links	x5.1	identifying potential partners and blocks to progress	Gioia, Weick, Daft and Lengel - sense-making	Yes - as knowledge is new, there is a need to exchange and challenge to build understanding	o2, o6	Sense-making via diverse stakeholder interactions and an integrating role, also help create visible position in ecosystem	We've also done some market research, or market intelligence work to understand our potential customers and if they would contract with us. That is not just the service groups or providers in the Trusts, we are aiming for a mixed income stream. DH1-1
e6	Business model mapping exercises	c7	Business models in ecosystem not generally established	p7	Identify viable and sustainable model to deliver value and meet vision -	x6.1	Need to develop a viable model for the venture, sources of funding / income not clear	Gioia, Weick, Daft and Lengel - sense-making	Yes, evidence that diversity of stakeholders and broader legal, IP issues make the decision challenging.	o4, o5, o7	Sustain- identify solutions that ensure venture is viable. Shape - see opportunities to create and capture value.	*Business Model is to engage, identify problems and solutions, create IP and develop offerings that can then be delivered by others (for royalty) or license to other providers (source: draft business plan)*
e7	Mapping value from different stakeholder perspectives - 'persona'	c5	Prior digital solutions not delivering promise	p5	Desire to add value and make a contribution to health outcomes	x7.1	Want to ensure solutions are valuable to patients and providers and can deliver sustainable income to keep venture going	Sarasvathy, Garud, Sydow - shape	Yes - examples, of seeking to create value from several perspectives and where they can create future value	o4, o6, o7	Shape - credibility and advantage	Explicitly look at 'value' from patient perspective in terms of outcome and experience. Look at value from practitioners' perspective in terms of effectiveness and efficiency. Looks at wider impact to Trust/CCG in efficiency terms (cost).
						x7.2	Want to ensure they are sen as credible in a nascent ecosystem		Yes - evidence of desire to be seen as credible in ecosystem, as important precursor to building relationships			Above all its important to be seen to be 'credible'. We need that to create legitimacy with patients and HCPs. So, as well as ideas, we have to bring 'assets' - examples of things we have made happen, and delivered. That lets people really understand what you are doing. DH1-1

ECPO Analysis
Case: DH1

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
e8	Development of own Catalyse, Incubate, Adopt and Embed process	c6	NHS 'bureaucracy' and inertia	p8	Need agile process to deliver solutions in an efficient way	x8.1	Need for simple processes, to fit organisation scale and culture. Existing incumbent models too complex	Ries - efficiency / lean	Yes - partial, aiming to deliver 'lean start-up'	o8	Lean-start-up - Capability building	Team aware of Lean Start-up principles, see as valuable approach. Process is simple lifecycle approach
						x8.2	Desire to be creative and develop 'own' solutions	Amabile - Creativity	No, whilst there is evidence they are looking for creative solutions, they appear happy to use existing tools where suitable			no evidence
e9	Developing simple Go/No go criteria in place.	c7	There are no established processes, 'rules' or criteria to go/no go. Existing one are bureaucratic and inefficient	p9	Increase objectivity in decision making	x9.1	Need for simple processes, to fit organisation scale and culture. Existing incumbent models too complex	Ries - efficiency / lean	Yes - partial, aiming to deliver 'lean start-up'	o8	Lean-start-up and agile ways of working (see The Lean Start-up, Eric Ries)	Team aware of Lean Start-up principles, see as valuable approach. Process is simple lifecycle approach
e10	Broadening activities to different geographical areas and national bodies	c8	Network remains fragmented, with disperse and diffuse knowledge and resources	p10	Increase credibility beyond local area and obtain some positional advantage to help deployment	x10.1	Increase opportunities and position in field	Sarasvathy, Garud, Sydow - shape	Yes - evidence of desire to be seen as credible in ecosystem, as important precursor to building relationships	o4, o7	Shape - credibility and advantage-seeking	We are well connected locally and continue to spend a lot of time networking. We are always making new connections. We are reasonably well known locally, so people come looking for us too. More broadly we are connected to NIB and some of their work streams; so that gives us an opportunity to influence at national level, particularly on Open Source software strategy. I have also been to meetings with Tim Kelsey (NHS National Director for Patients and Information) and other NHS England meetings. So we are building broader connections, particularly on digital participation, so informally we are good, but in other areas like HSCIC we are not so well connected. DH1-1

ECPO Analysis
Case: DH1

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
e11	Managing ad-hoc Alliance partner formation	c9	NHS bureaucracy and lack of Framework	p11	Manage relationship with suppliers	x11.1	Manage relationship with small number of suppliers in near term	selection	Yes, limited initial choices	o3, o9	Selection	The other things we are trying to move on is to be able to make the decisions on our own pre-agreed criteria and not 'standard NHS' one. For example we recently went out for quotes and a Sheffield agency came in a lot cheaper, but it was clear they had really not got enough in their bid to do the job. DH1-2
				p2	ensure solutions were appropriate and acceptable	x11.2	Need to identify collaborators, sources of knowledge	selection	Yes, selection processes are evolving	o3, 09	Selection	We still don't have a framework. We have developed a draft, revised it , sent it back for comments and are still waiting. Over 2 months now. Its clear we need a little more rigor and structure, but some requirements are quite painful – for example - if we do not state in the advert that we intend to interview, we cannot, even if it makes sense to do so, so make the selection. DH1-2
				p12	Work to develop longer term solution via Framework	x11.3	Need for sustainable model	sustain	Work to develop longer term solution via Framework	o5, o8, o9	Sustain - invest in longer term solutions, modifying process for longer term	I'd describe the common interest as something more, there needs to be 'congruence' a real alignment, not just in terms of the outcome, but also cultural and how you are going to do it. Connections do not just happen. You need to 'cultivate' to create the right opportunities. That is where I see this spirit of generosity and being open, learning together as being important. DH1-1
e12	Continually refining internal processes	c7	There are no established processes, 'rules' or criteria to go/no go. Existing one are bureaucratic	p8	Need agile and lean process to deliver solutions in an efficient way	x12.1	Need to demonstrate early success	Shape - Sarasvathy, Garud, Sydow	Yes, need to justify funding provided and create real output with evidence of benefits	o4, o6, o8	Shape - legitimacy-seeking	I think that as we have evolved somethings have changed. But some things are core. Our approach is what you might call a 'spirit of inquiry' we want to foster 'learning together'. That's a very different approach to a Tech company coming along or even a HCP coming along with a 'solution'. Our approach is about creating buy-in from all users. To do that you need to be prepared to 'learn in public'. That means continually connecting via debates, workshops, meetings, 'show and tell'. DH1-1

ECPO Analysis
Case: DH1

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
			and inefficient					Selection - experiential learning	Yes - need to refine criteria, experiential learning process	o3, o8	Selection, experiential	We have introduced new decision points – Providers need to provide data at Discovery Day. We can pull out at DD phase if there is no real demand or data. If we progress, we build a prototype and seek further use/provider feedback. Again if demand, or prototype and spec are not right we can pull out and also we need commitment agreement (of providers time to enable development and adoption). Typically each project needs a Project Sponsor (specialty / department leader level) who secures funding, to move forwards. DH1-2
								Shape - Sarasvathy, Garud, Sydow	Yes, need to justify funding provided and create real output with evidence of benefits	o4, o6, o7	Shape - legitimacy- and advantage -seeking	Its also important that what we have done is visible, so people can see our track record. So another important part of our role is to curate and make public. So, you will find searchable content on our website, in our blogs etc. DH1-1
						x12.2	Need to improve processes and performance	Teece et al dynamic capabilities	Partial - there is no pattern of continually SST actions. Changes are made	o9	Broad small changes, shaped by management, rather than continual experimentation?	Observations
								Ambidexterity - Birkinshaw et al	No. There is no evidence of range of capabilities across organisation - small new team	o9	Broad small changes, shaped by management, rather than continual experimentation?	Observations
						x12.3	Desire to be creative and develop 'own' solutions	creativity	No, whilst evidence looking for creative solutions, they appear happy to use existing tools where they exist			no evidence

Appendix A5

ECPO Analysis
Case: DH1

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
e13	Writing Conference and academic Papers	c3	Knowledge and technology gaps across ecosystem (especially in user groups)	p13	Increasing awareness across ecosystem	x13.1	Need to grow network and position within it	Shape - Sarasvathy, Garud, Sydow	Yes, partial - there is belief solutions is good, so looking to 'promote' it	o4, o6	Shape	Legitimacy-seeking, advantage-seeking
		c2	Ecosystem of potential partners did not exist at the outset. Increase awareness across ecosystem			x13.2	Need to identify other sources of knowledge and solutions	search / shape	Yes, partial - also provides opportunities to reach and engage others - as potential suppliers and customers	o4,o6	Shape	*We are well connected locally and continue to spend a lot of time networking. We are always making new connections. We are reasonably well known locally, so people come looking for us too. More broadly we are connected to NIB and some of their work streams; so that gives us an opportunity to influence at national level, particularly on Open Source software strategy. DH1-1.*
e14	Internal Business Plan regularly refined	c7	Business models in ecosystem not generally established	p7	Identify viable and sustainable model to deliver value and meet vision	x14.1	Business Model is to engage, identify problems and solutions, create IP and develop offerings that can then be delivered by others (for royalty) or license to other providers	selection	Yes, partial - the key elements of required model are understood	o3, o8, o10	Selection, Sustain	The plan though is still to form a company limited by guarantee, 100% owned by LYHFT, and run as a not for profit. So any surplus will be reinvested in the business and services. DH1-1
				p14	Lack of clarity in viable business models, DH1 learning as it goes.	x14.2	Unsure as to what is best option, so defer decision, but engage more widely to build learning and understanding	Wieck - sense making	Yes, partial, there is insufficient understanding to be confident in any one choice, so keeping options open and continually building network	o2, o8, o10	Sense-making - experiential learning process	I've been paying more attention to National and local networks. We have run lots of Local show and tell events; we get good feedback, but its quite draining to run. We also run lunchtime learning – and peer consultations, and took on the National Event – People Driven Digital. I've also written a White Paper, which I'm presenting at the King's Fund digital event and then 'taking on tour'. I also took on running the Awards event on the 3 July, but that had the benefit of also providing Case Studies for the White Paper. DH1-1
		c9	NHS 'bureaucracy' and inertia	p15	Need to address concerns of NHS Trust	x14.3	Constraint in options available.	Selection	Yes, partial	o8	Capability limiting?	Note: no strong evidence of inertia

A5.4 Case MLD ECPO analysis

ECPO Analysis
Case: MLD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
e2	Regular Meetings with entrepreneurs, tech companies, developers, funders and opinion leaders	c1	Limited understanding of ecosystem, innovation opportunity and stakeholders	p2	Need to identify collaborators, sources of knowledge to ensure solutions were appropriate and acceptable.	x2.1	Systematic search (initially)		Yes - there is a need to identify actors and knowledge holders	o1, o2, o6	Strategic Search (both local and distant - using structured and snowball approaches)	MLD2: "So we'd contact 1 or 2 people, and it would take 1 or 2 weeks for them to reply, slow. ... There are a number of highly influential stakeholders, and to be honest without their buy-in its hard to connect."
						x2.2	Use network to extend search (snowball), continue to search and engage	Goodman - snowballing Rosenkopf / Nerkar- distant knowledge	Yes - it is a novel area, so need approach to scan 'distant' knowledge and sources	o1, o2, o6	Strategic Search (both local and distant - using structured and snowball approaches)	MLD4: "I think the technology is novel. I've had my own people do some basis due diligence, so I am aware of […] and […] and others, but this appears different. If it works it offers a different approach, and importantly an earlier diagnosis."
												Observed meetings with Tech[P], VCs[F], VC [B] etc
						x2.3	Interchange of idea and challenges - sense-making	Gioia, Weick, Daft and Lengel - sense-making	Yes - as knowledge is new, there is a need to exchange and challenge to build understanding	o2, o6	Sense-making via diverse stakeholder interactions and an integrating role	MLD1: "To be honest, it's a bit like Brownian motion. You are forever moving around, bumping into different people. And you cannot predict before hand whether they will add value or not, or even immediately after. Also its something about when you do business and have the meeting. so it's not pre-determined, it seems completely random. You might expect them to be interested based on your prior knowledge, but its not always like that, and it might just be timing or it doesn't fit their exact interest."
e3	Took part in Innovation competitions (multiple)	c4	Opportunity to showcase innovation	p3	Need to be visible and attract funding	x3.1	Interchange of ideas to identify value	Gioia, Weick, Daft and Lengel - sense-making	Yes - as knowledge is new, there is a need to exchange and challenge to build understanding	o2, o6	Sense-making via diverse stakeholder interactions and an integrating role	MLD1: "Feedback from our bids was we need to make 'more inventive' or its not properly understood. What is the inventive or innovative step?"
		c5	Availability of competition funding									
e4	Meetings with investors, brokers, and conducting IPO	c2	Access to funding			x3.2	fuding to progress innovation			o6, o10	Funding enables development and creation of value network	Observed meetings at VC[F], VC [B], Broker [B]

ECPO Analysis
Case: MLD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
e5	Engaging GPs and other HCPs	c6	Technology new to HCPs	p4	Get feedback from potential users, customers	x4.1	Meetings with prototypes or presentations to obtain feedback	Gioia, Weick, Daft and Lengel - sense-making. Carlile- boundary object	Yes, use simple presentations to explain concept	o2, o3, o4, o6, o7	Engagement increase visibility, obtains feedback to help better position firm and innovation	MLD1: "So we started to speak to Doctors, patients, providers, charities, specialists etc and use our personal contacts to talk to them and capture key points in a spreadsheet. We aimed to record the problems they had, why they would use our product, what problems it solved."
e6	Meetings with potential collaborators (contractors) and technology companies	c1	Technology companies interested in new technologies and potential partnerships	p3, p5	Potential to attract funding and partnership	x5.1	Aim to attract major partners (long term)	Shape - Sarasvathy, Garud, Sydow	Yes,	o2, o6	Shaping innovation and development path	MLD1: "So, you have to invest in relationships, and it consumes your resources. But back to our network, we are building it, we have the first few critical ones in place and then we are working through them, to see more."
		c7	Software contractors available locally to do early development work	p6	Potential to develop a testable prototype at low cost	x5.2	Make near term progress on innovation and help de-risk	Shape - Sarasvathy, Garud, Sydow	Yes	o6	Shaping and sustaining (reducing risk)	MLD1: "We met Jean and Johannes through ... and a hack-athon. They are super developer's They are young, but smart and very professional in developing software."
e7	Mapping stakeholders and understanding the emerging ecosystem	c1	Limited understanding of ecosystem, innovation opportunity and stakeholders	p2, p7	Need to develop wider understandin g and stronger ecosystem links to support decision making and identify long term partners	x6.1	identifying potential partners, future value network and blocks to progress	Gioia, Weick, Daft and Lengel - sense-making	Yes - as knowledge is new, there is a need to exchange and challenge to build understanding	o2, o9	Sense-making via diverse stakeholder interactions and an integrating role	MLD1: "We find people, we might make a little progress. But they don't all work out. We are continually exploring new possibilities, in terms of partners, investors and people we could work with for trials etc. I think one of the challenges here is unless you have the finance in place and can buy services, you need to have several options in play, because one might not come off, and you don't have any leverage. So they can just walk away. So building the network is critical."
												MLD1: "Have had discussions with Tech [P] about a European funded project. They want to form a consortium with us, and a large ... Health Insurance company. "
												MLD1: "When we first started we though that pharma might be sweet spot, as the test would support prescriptions. But after talking to J&J and Roche we realised we were not aligned. Their focus is on biomarkers that specifically link to their drugs."

ECPO Analysis
Case: MLD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
e8	Mapping value from different stakeholder perspectives	c8	Lack of understanding of 'value' for new technologies	p2, p4	Desire to add value and identify key potential stakeholders	x7.1	Want to ensure solutions are valuable to others	Sarasvathy, Garud, Sydow - shape	Yes - examples, of seeking to create value from several perspectives and where they can create future value	o2, o4, o7	Understanding and then trying to Shape - a viable model and advantage	MLD1: "So our entry point is going to be the one that's easiest and quickest to validate and the fastest to adopt. In terms of unmet need, we think screening is the biggest opportunity, with a high value. The current approaches are crude, paper based, time consuming, they are the bottleneck and result in under diagnosis."
						x7.2	Want to identify viable business models		Yes - needed for investors			MLD1: "Our business model is to offer the technology hardware/software free, but charge per test, so SaaS, a Service model."
e9	Development Business Plans	c2	Access to funding	p3	Need to identify investors requirements and attract funding	x8.1	Need for clear vision, business plan and funding needs	Gioia, Weick, Daft and Lengel - sense-making	Yes, seeking to position as valuable innovation	o2, o7		MLD4: "It was focussed on a particular injury / disease area and the [MLD] pitch was a little adjacent, but relevant. So, we got talking. Agreed to meet up. Which we have done a few times, informally."
e10	Undertaking User Needs and exploratory studies (overseas)	c6, c8	Novel technology requiring data, but limited funding	p3, p6	Need to develop data to demonstrate credibility and potential, with minimal spend	x9.1	Reduce risk and create value at least cost	Shape - Sarasvathy, Garud, Sydow	Yes,	o6, o7	Shape innovation, but also sustain, as risks reduced.	MLD1: "So, if we do planed trail we are essentially doing a head to head…. I spoke to the investigators this week. They are doing their own risk assessment. "
e11	Engaging NHS Trusts and other R&D organisations	c9	Viable locations for clinical studies. Desire in some Trusts to develop innovations	p8	Need access to credible development partners for clinical studies	x10.1		Shape - Sarasvathy, Garud, Sydow	Yes, clinical studies critical to shaping innovation	o6, o10		Observed meetings with NHS Trust
e12	Establishing partnership with Gaming Technology company	c10	Limited organisations who could develop rapid response software for testing	p8	Need for technologicall y capable firm as partner	x11.1	Creates capability to develop test on iOS devices	Shape - Sarasvathy, Garud, Sydow	Yes, provides enabling capability and technological advantage	o2, o3, o4, o7, o10	Partnership enables technology to be developed on new platform with high performance	Observed Meeting with developer Tech [O] and draft specification

ECPO Analysis
Case: MLD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
e13	Establish simple governance processes and meetings	c11	Investors expectations for corporate governance	p9	Need to meet investors expectations and manage key decisions	x12.1	Regular management meetings (weekly) and infrequent Board meetings	Ries - efficiency / lean	Yes - partial	o8, o11		Observed [MLD] Management Meetings
e14	Undertaking formal risk reviews	c12	Novel technology with wide range of risks	p10	Need to identify and reduce risks to progress and increase valuation	x13.1	Comprehensive and integrated review following ISO standards		Yes,	o5	Sustain, reduce risk	Observed Risk Review (15/06/15) and access to Risk document
e15	Developing internal processes and policies	c13	Regulatory requirement to have ISO13485 QMS and associated processes	p11	Need to meet regulatory requirements to obtain EU and USA approval	x14.1	Need agile process to deliver innovation	Shape - Sarasvathy, Garud, Sydow	Yes, need to justify funding provided and create real output with evidence of benefits	o4, 09	Shape - legitimacy-seeking	Observed [MLD] Management Meetings. Access to draft QMS document (21/10/16).
						x14.2	Need documented process to meet regulatory needs		Yes	o9	Shape - legitimacy-seeking	
e16	Changes in senior personnel	c14	Limited experienced people available to team	p12	Individuals unable or unwilling to work within start-up culture	x15.1	Experienced individuals struggling with start-up culture and ambiguity of convergent innovation		Yes, partial - also a culture issue	o3, o11	Selection, Sustain	MLD1: "We then engaged another MBA student, he had been a senior director in [...]. He came across as very knowledgeable, but his interest wasn't. there I think he just wanted it on his CV. He provded no real input. In fact he wasted a lot of time. He always had excuses, so it ended up as a dead end. Fortunately the disengagement was smotth. Its just his mindset was different, not a start-up person."
						x15.2	Team diverse and difficult to work with	Personality issues	No, team diverse, but more about individuals' willingness to work in ambiguous way			

Appendix A5

ECPO Analysis
Case: MLD

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize - case evidence or quote
				p13	Evolving understanding of MLDs capability needs as innovation progresses	x15.3	Unsure as to what is best skills mix in team. Explore options and fit first before making commitment.	Wieck - sense making. Cultural fit.	Yes, team building, Belbin	o2, o9, o11	Sense-making - experiential learning process	MLD1: "He's continued to work with us, introduced us to other medics and is helping design the trials. So we've actually taken him on as Medical Director. As we need that now we are moving into some trials."

A5.5 Case DH2 ECPO analysis

ECPO Analysis
Case: DH2

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
e1	Engage with potential partners and funders at pitch days.	c1	Poor understanding of opportunity and ecosystem	p1	Ensure DH2 had access to partners and funding	x1.1	Need to be visible	Search - Pandza et al	Yes,	o1, o6	Strategic Search and visibility	"...we won a Scottish Enterprise High Growth Start-up award. " DH2-2
e2	Obtained SE funding to develop 'pilot concept'	c2	Open competition for early phase funding	p2	Need to raise funding and profile	x2.1	Open Competition	Sustain - enables investment to support venture	Yes, evidence from case, they are keen to do this. Strong Alliance formation is recognised innovation path (Garud et al)	o3	Sustain	"..Scottish Enterprise High Growth Start-up award. And we started their global programme, with access to potential investors. Being part of SE high growth programme gave credibility. In Central Belt, only 1% of start-ups meet the criteria, so it was good due diligence for investors. " DH2-2
e3	Meetings with pharma and pharmacy	c3	Variable and conflicting feedback	p3	Looking to better understand opportunity	x3.1		Sense-making (Wieck)	Yes - taking in views of different stakeholders and modifying response	o2, o6	Sense-making, credibility seeking	"Our role is to make sense of that [feedback] and identify which feedback is going to help us move forwards." DH2-1
e4	Pitched to US technology companies	c2	Open competition for early phase venture funding	p2	Need to raise funding	x4.1	Identify Alliance partners that provide credibility and are attractive to investors	Searching, Sense-making, Selection	Yes - exploring potential partners, looking at several options, using network to explore others	o1,o2,o3	Searching, Sense-making and Selection	"… we were put in front of Walgreen, and got the nod. They really liked it and put us in touch with Apple. Apple gave great feedback, 'probably best user engagement they'd seen'. They wanted to showcase internally, but we didn't give permission." DH2-2
				p4	Need to raise profile with potential investors and collaborators							

Appendix A5

ECPO Analysis
Case: DH2

E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
e5	Engaging potential Alliance partners	c4	Major pharma etc. want to link to start-up venture	p5	Need partner as potential channel to market and revenue source.	x5.1	Form long-term alliance partnership	Alliances	Yes, evidence from case, they are keen to do this. Strong Alliance formation is recognised innovation path (Garud et al)	o4,o5	Sustain and Shape	"But we want to engage big pharma before its too developed, to ensure it meets their needs and has value. Ideally we are looking for one to partner with." DH2-2
e6	User engagement	c5	Understanding value proposition	p6	Need to understand value to aid design and value proposition	x6.1	User engagement and involvement in design	Sense-making (Weick) and User co-creation (von Hippel)	Yes - early evidence, but not evident later (?)	o2, o6	Sense-making, creating credibility	"Apple gave great feedback, 'probably best user engagement they'd seen.' " DH2-2
e7	Targeting Scottish investment community for investment	c6	Local network	p7	DH2 focussed on using existing knowledge and network	x7.1	Believe that their existing network is sufficiently broad/strong to provide solutions	search	Yes - had not engaged widely, so then subject to limitations of the small investment community.	o1?	Search -but note quote - *search is narrow and predefined by existing knowledge or network*	"Once we are ready to engage, I will do mapping. Using my own network, as start. Which is based upon .. many I know personally, then I go to people who have introduced me, then finally people who know people I know." DH2-1
						x7.2	Scottish Enterprise (SE) Policy?	Policy restriction	No, no evidence SE restrict investment although do expect firm to be Scotland based			
e8	Failure to secure follow on funding in Scotland	c7	Scottish investment environment is limited (in terms of scale, scope and interest)	p7	DH2 focussed on using existing knowledge and network	x8.1	Believe that their existing network is sufficiently broad/strong to provide solutions	Search	Yes - had not engaged widely, so then subject to limitations of the small investment community.	o1, o6	Search - but is narrow	"One of the big challenges is in the Investment community – in Scotland (it's typically conservative, risk averse, poor investment funnel, only interested in SEIS/EIS tax efficiency, mainly 65+ men, strong opinions, but no knowledge). Model is ... always looking for £250k, and to go for little and in tranches). DH2-2

ECPO Analysis
Case: DH2

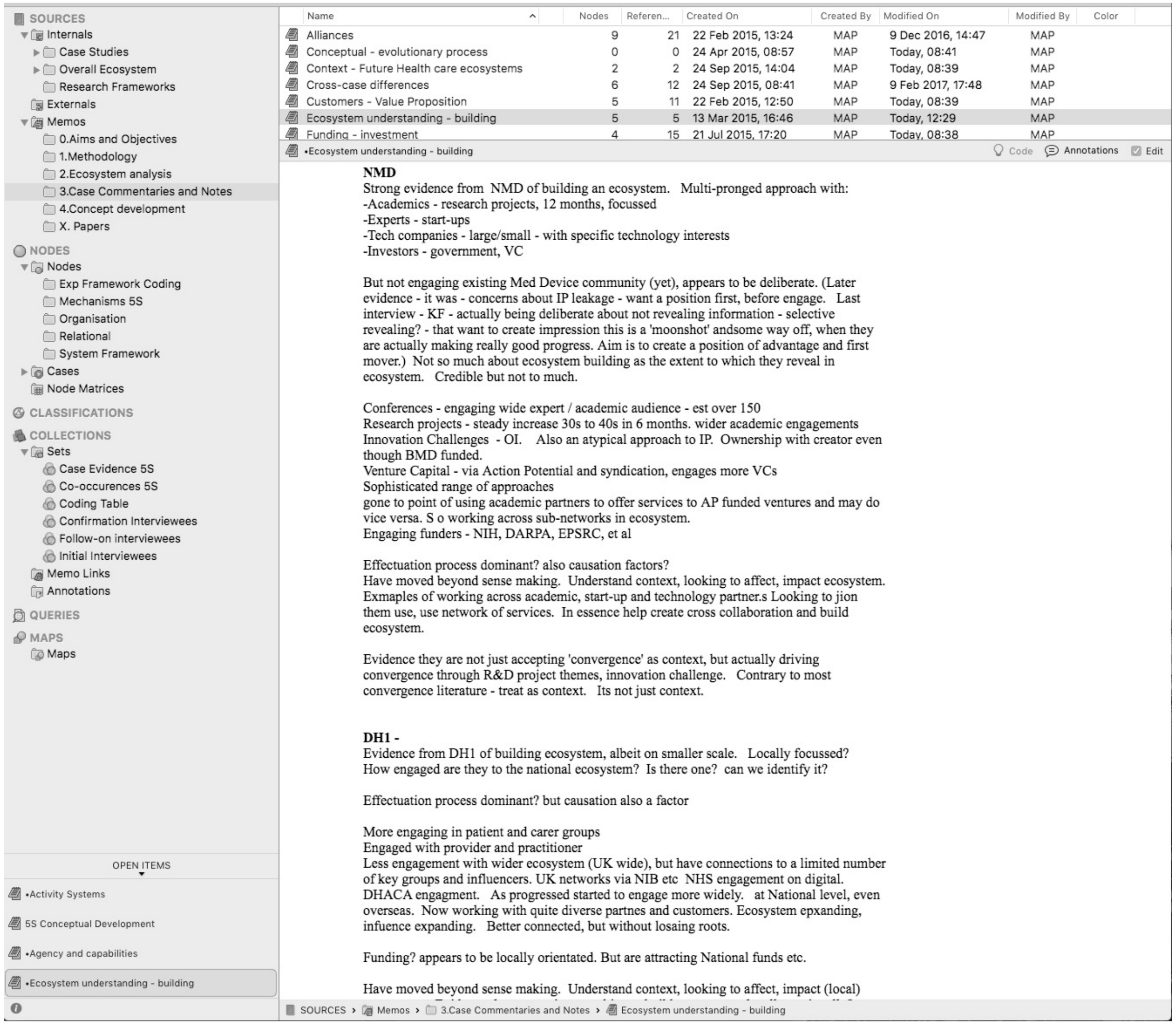
E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
e9	Failure to obtain signficant engagement for funding in London	c8	Bigger market for biotech funding, access to capital	p8	Failure to raise investment locally drives need to engage with wider community	x9.1	Lack of previous engagement means sense-making and understanding remain poor, business model is still under-developed and was challenged by investors	Sense-making (Wieck)	Yes - had not engaged widely, so then subject to challenging feedback	o2, o6, o7?	Sense-making, creating awareness, but not achieving position of value	"[Investor] thought market was payers. ... She also struggles with the value proposition as we proposed it. She suggested we speak to payers." DH2-1
						9.2	London based investors not interested in SE funded venture	selection	No, no evidence to support this in London VC community			
e10	Internal Business Plan and business model changed	c9	Business models in ecosystem not generally established	p9	Identify viable and sustainable model to deliver value and meet vision	x10.1	Belief in prior research results and previous experience	selection	Yes, partial - the key elements of required model are understood	o3,o5, o11?	Selection, Sustain, clear on governance	"I only work with people I know or have been introduced to by someone I trust. ... For all my clients I have an approach or process where 7 factors are tracked. They cover everything from IPR, the value proposition, who the competition is , business model, etc , all ahead of fund raising." DH2-1
				p10	Lack of clarity in viable business models, DH2 learning as it goes.	x10.2	Believe they know best option, but then find that this is not supported by potential collaborators	Wieck - sensemaking	Yes, there is insufficient understanding to support their choice, but do not keep alternative open and do not build network	o2	Sense-making	"We've done good research. We have looked at strategic positioning. The software is specified, actually its about 60% done (as a favour). We are close to having it fully specified. Then we had demo hardware. If you remember we had someone from FoxConn Europe. So we had a device and Bluetooth. We had also worked out our Big Data app. But needed to confirm the algorithm." DH2-1

Appendix A5

ECPO Analysis
Case: DH2

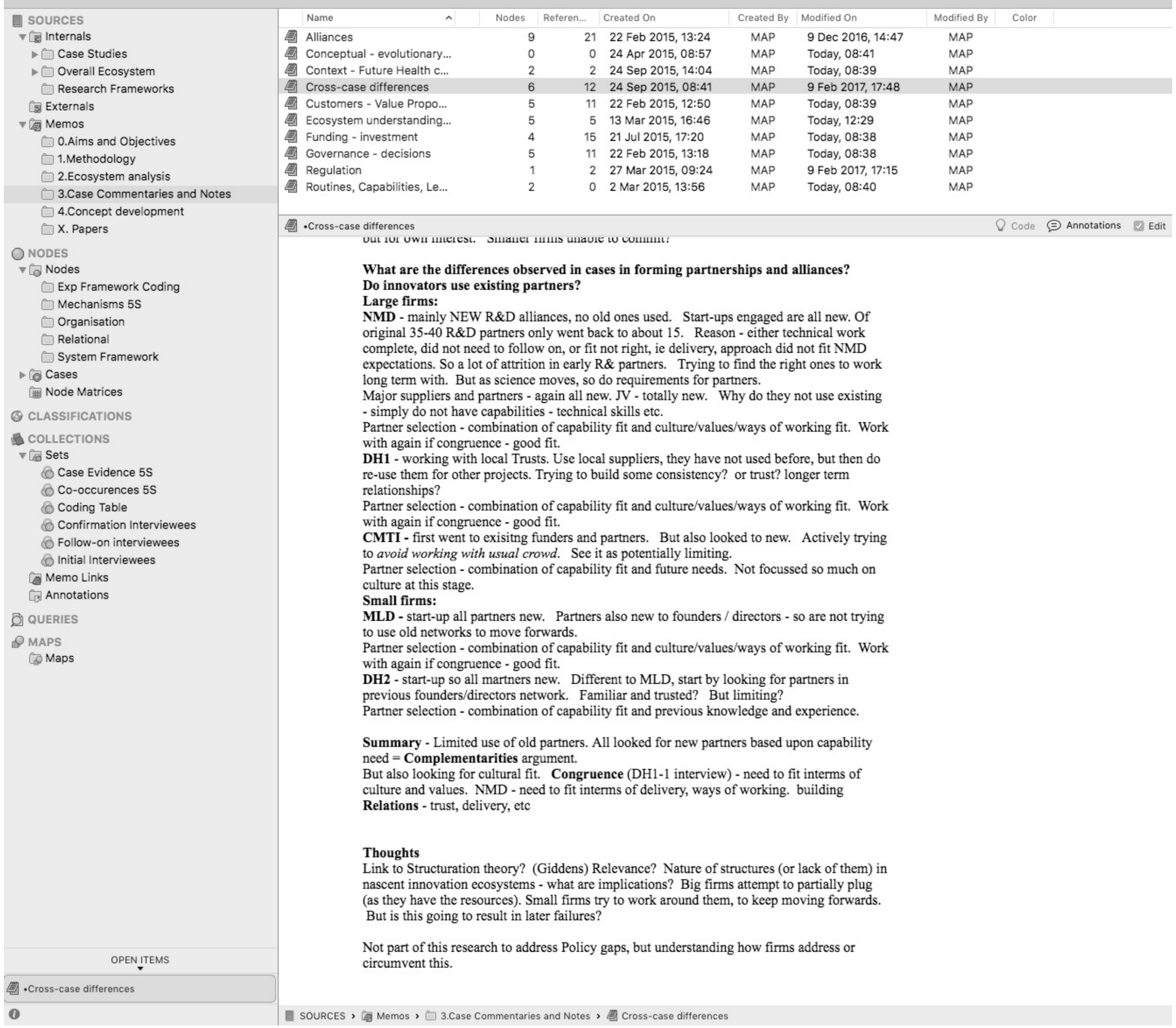
E	Event - Interview, Observation or Document (e) - identified from Case Summaries	C	Conditions or Context (in innovation ecosystem) (c)	P	Likely Causal Powers and Liabilities (tendencies) (p, l)	x	Possible Mechanisms (process, structure) (x)	Theoretical foundation	Plausible? Rationale	O	Suggested Object - Mechanism, process, capability	Contextualize
								Wieck - sense making	Yes - had not engaged widely to ensure case was robust before pitching, so then subject to diverse feedback	o2, o6	Sense-making and positioning for credibility	"We've positioned it as 'Olly' a condition PA. So its more than a piece of software, its there as your helper. We've shown people the concept. The concept is it tracks habits and uses these and informatics to help identify ways to improve and support adherence. Our primary objective is adherence. We believe a 1% improvement in adherence is worth a lot to a big pharma company. So our focus is on pharma as a customer." DH2-2
e11	Challenging or negative feedback in pitches	c9	Feedback from potential partners, that model did not fit	p11	Need to address pharma feedback, but have not developed alternatives	x11.1	Constraint in options available.	Sense-making and selection	Yes, partial - evidence had not done sufficient sense-making before making major commitments.	o2, o3	Selection - processes narrow, tending to stick to initial plan. Failing to gain advantage or value position.	"Biolauncher were quite stern about where would get investment, but gave them options. [RG] rubbished our numbers, and others'. Sees £250k as nonsense. Asked to go away and start working on real numbers. Biolauncher thought market was payers. Seemed anti-pharma .. Rubbished GSK as option too. She also struggles with the value proposition as we proposed it. She suggested we speak to payers". DH2-2

Appendix A6 – Examples of NVivo Memo analyses

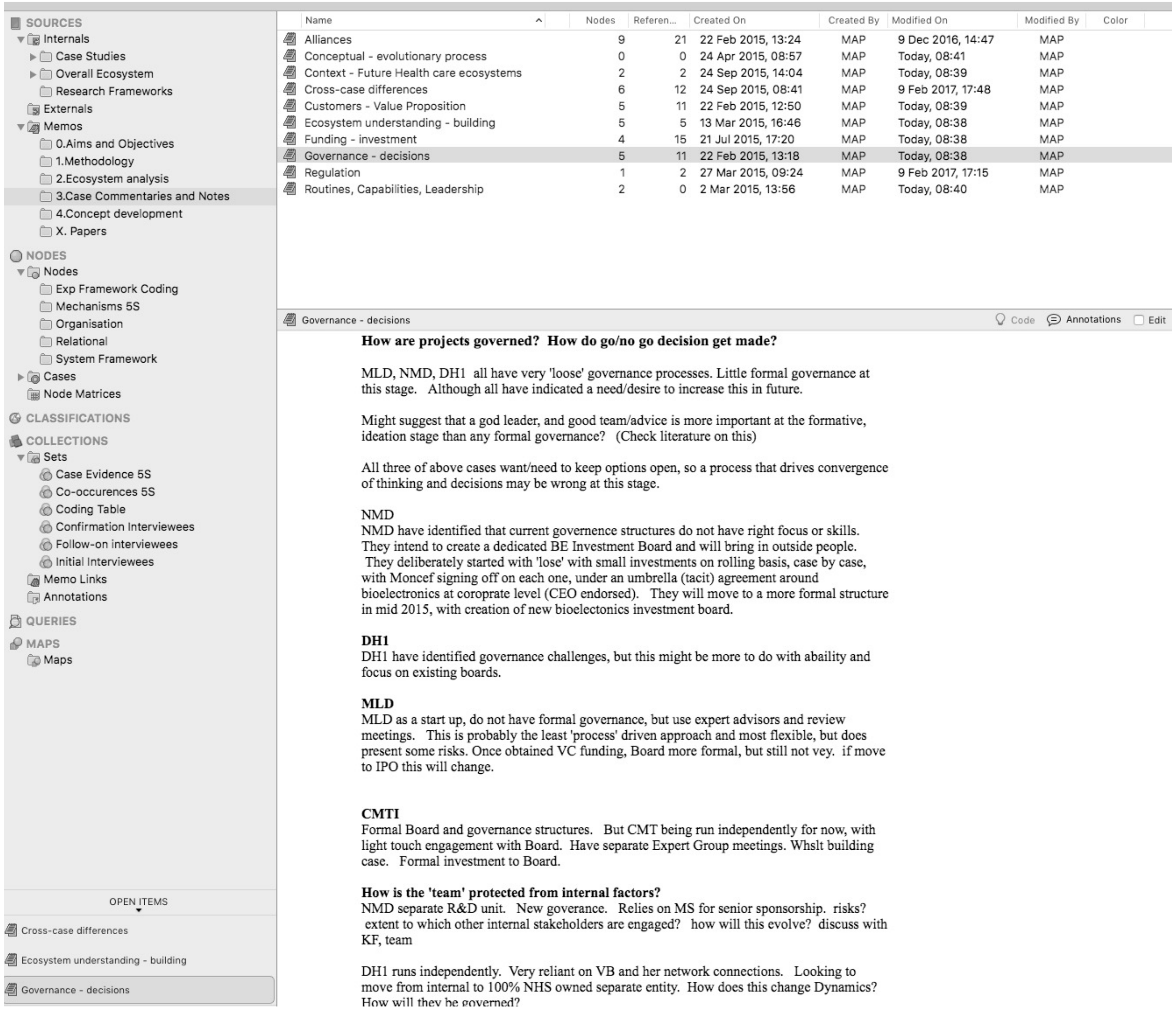


A6 Figure 1 Ecosystem understanding and relationship building

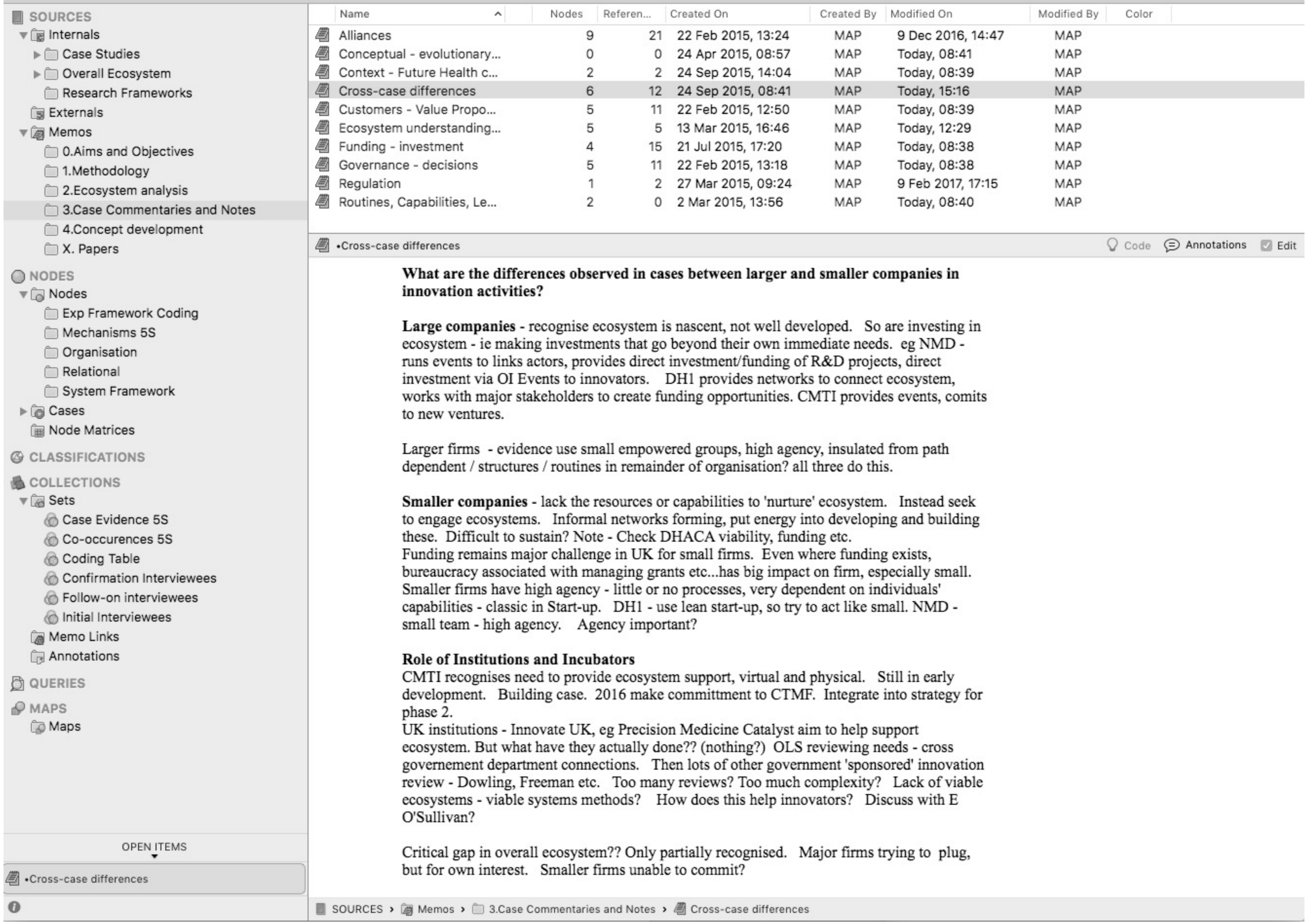
A6 Figure 2 Example NVivo memo for cross-case analysis of value propositions



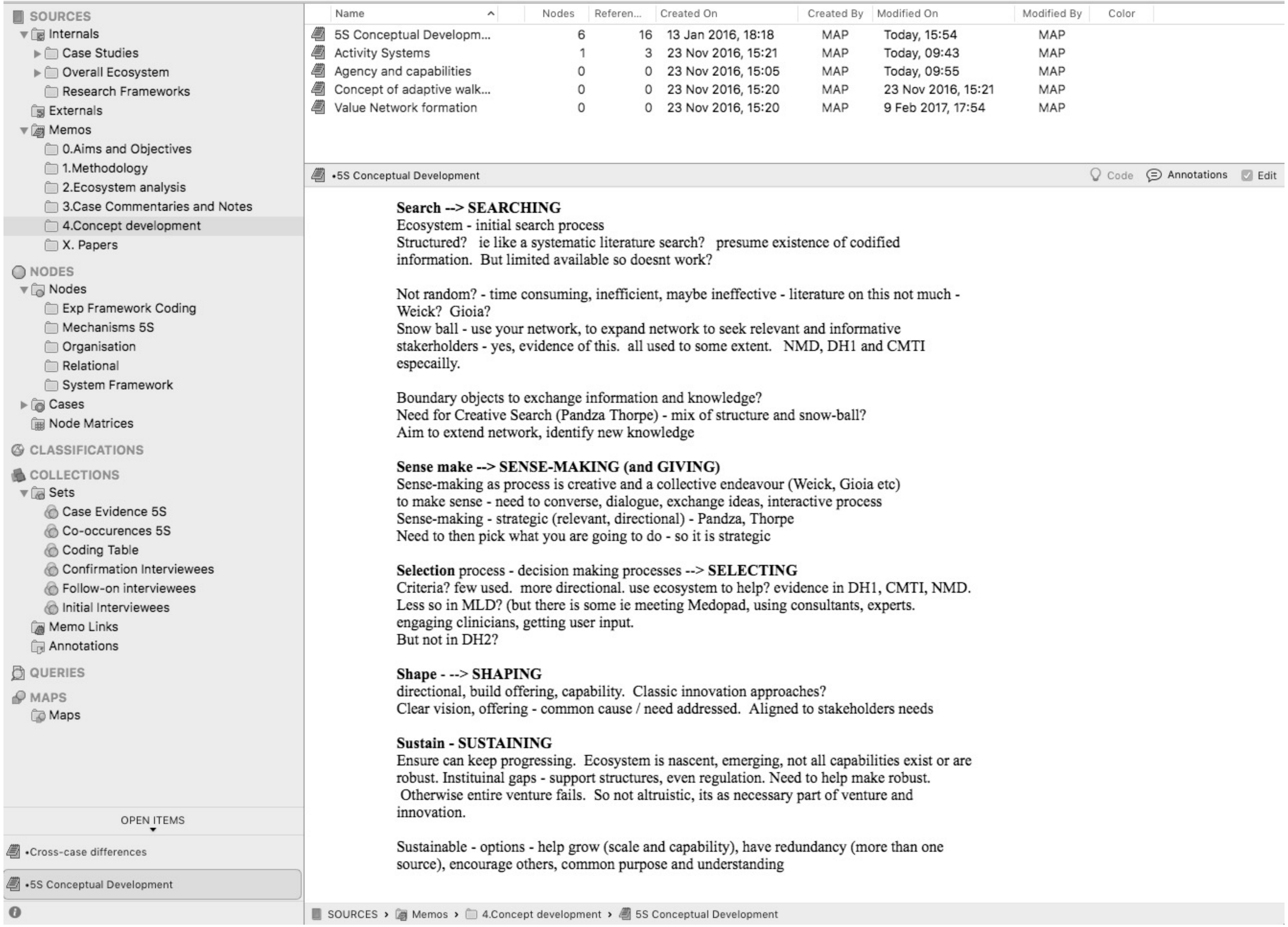
A6 Figure 3 Example NVivo memo for identification and formation of partnerships



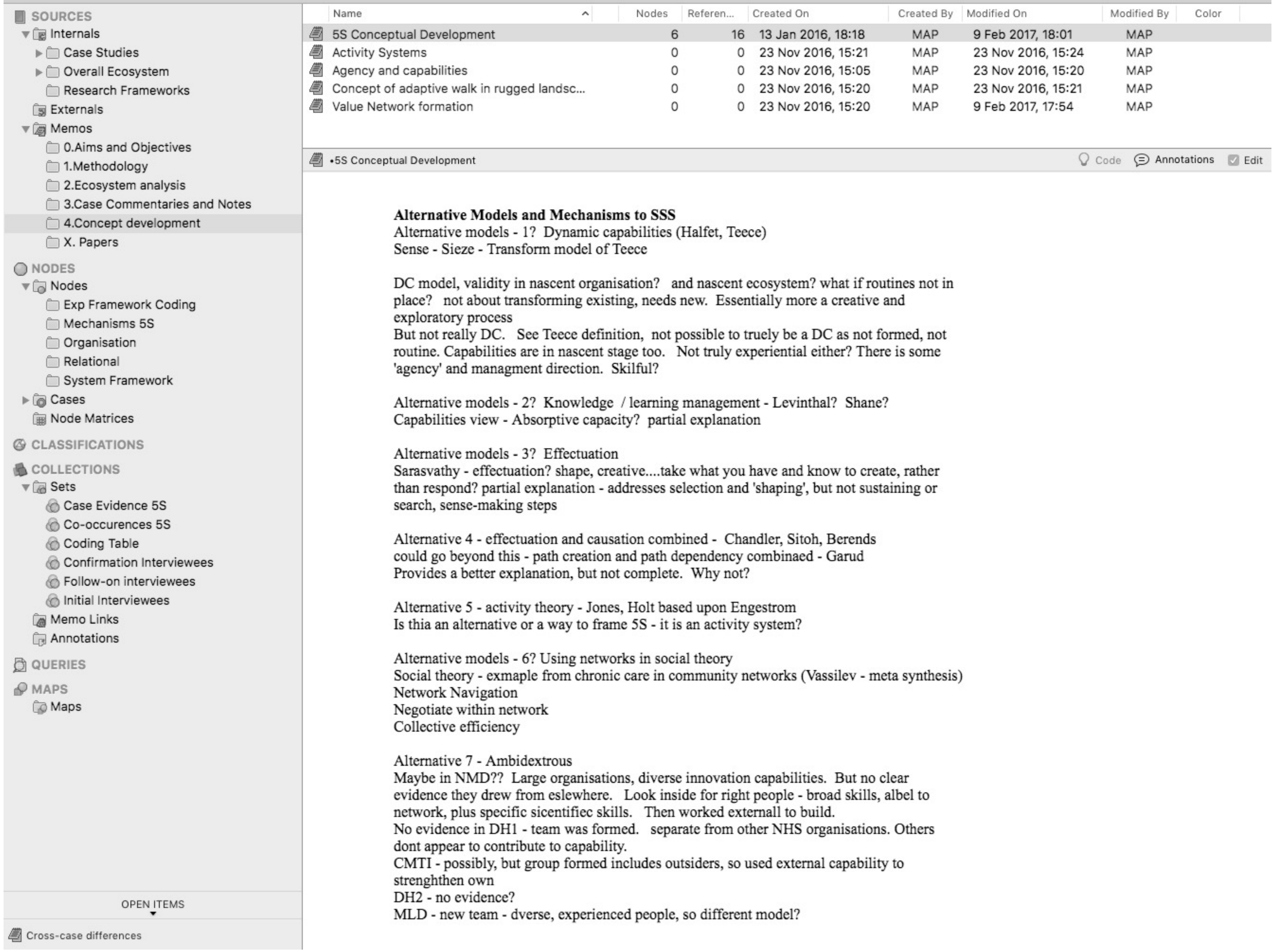
A6 Figure 4 Example NVivo memo for governance and decision making



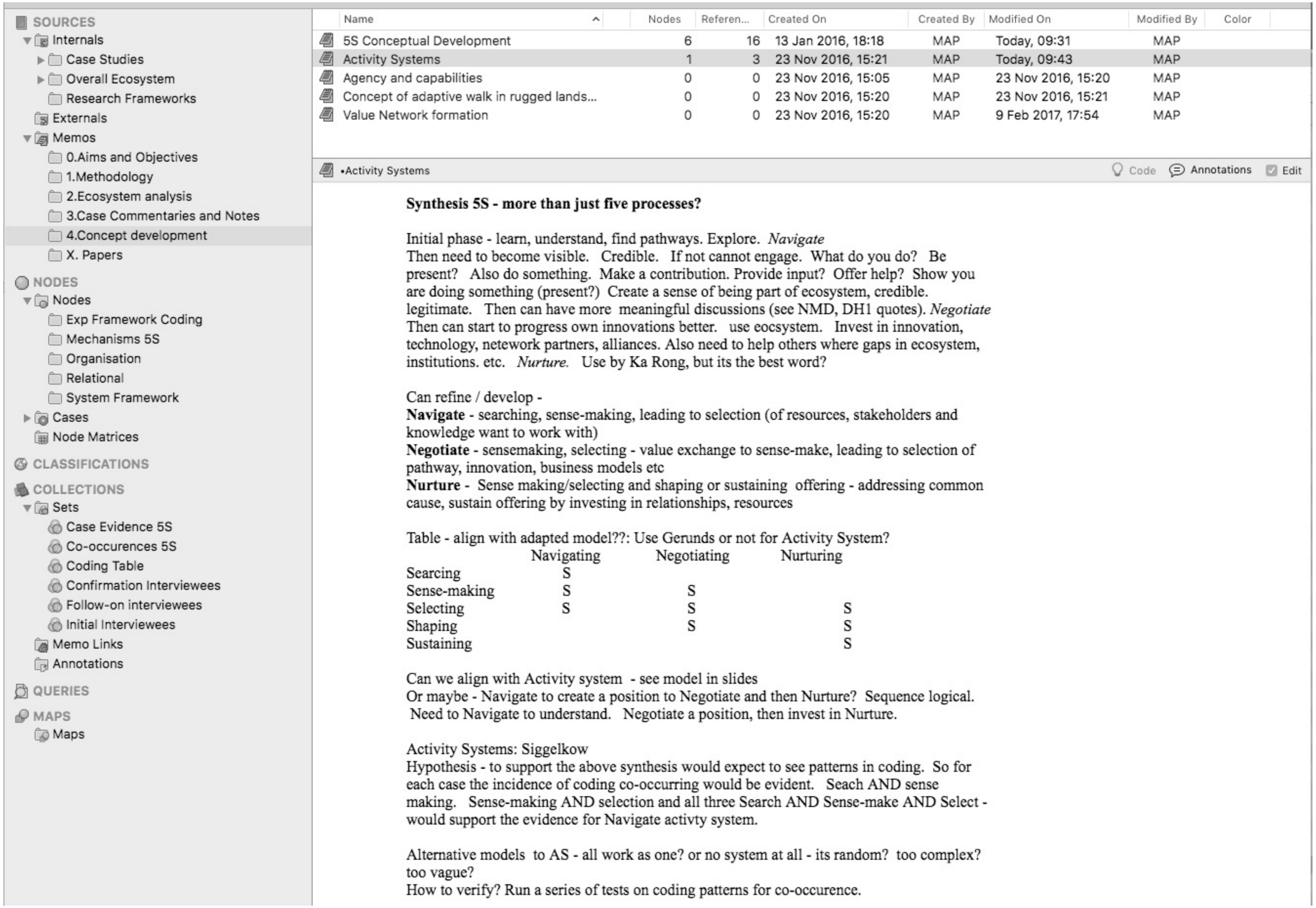
A6 Figure 5 Example NVivo comparison of large and small organisations



A6 Figure 6 Example NVivo cross case review of micro-processes



A6 Figure 7 Example NVivo review of alternative explanations



Synthesis 5S - more than just five processes?

Initial phase - learn, understand, find pathways. Explore. *Navigate*
Then need to become visible. Credible. If not cannot engage. What do you do? Be present? Also do something. Make a contribution. Provide input? Offer help? Show you are doing something (present?) Create a sense of being part of ecosystem, credible. legitimate. Then can have more meaningful discussions (see NMD, DH1 quotes). *Negotiate*
Then can start to progress own innovations better. use eocsystem. Invest in innovation, technology, netework partners, alliances. Also need to help others where gaps in ecosystem, institutions. etc. *Nurture.* Use by Ka Rong, but its the best word?

Can refine / develop -
Navigate - searching, sense-making, leading to selection (of resources, stakeholders and knowledge want to work with)
Negotiate - sensemaking, selecting - value exchange to sense-make, leading to selection of pathway, innovation, business models etc
Nurture - Sense making/selecting and shaping or sustaining offering - addressing common cause, sustain offering by investing in relationships, resources

Table - align with adapted model??: Use Gerunds or not for Activity System?

	Navigating	Negotiating	Nurturing
Searcing	S		
Sense-making	S	S	
Selecting	S	S	S
Shaping		S	S
Sustaining			S

Can we align with Activity system - see model in slides
Or maybe - Navigate to create a position to Negotiate and then Nurture? Sequence logical. Need to Navigate to understand. Negotiate a position, then invest in Nurture.

Activity Systems: Siggelkow
Hypothesis - to support the above synthesis would expect to see patterns in coding. So for each case the incidence of coding co-occurring would be evident. Seach AND sense making. Sense-making AND selection and all three Search AND Sense-make AND Select - would support the evidence for Navigate activty system.

Alternative models to AS - all work as one? or no system at all - its random? too complex? too vague?
How to verify? Run a series of tests on coding patterns for co-occurence.

A6 Figure 8 Consideration of processes as part of an activity system